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RADIATION DATA AND REPORTS

Volume 15, Number 7, July 1974

Radiation Data and Reports, a monthly publication of the Environmental Protection Agency presents data and reports provided by Federal, State, and foreign governmental agencies, and other cooperating organizations. Pertinent original data and interpretive manuscripts are invited from investigators.

In August 1959, the President directed the Secretary of Health, Education, and Welfare to intensify Departmental activities in the field of radiological health. The Department was assigned responsibility within the Executive Branch for the collation, analysis, and interpretation of data on environmental radiation levels. This responsibility was delegated to the Bureau of Radiological Health, Public Health Service. Pursuant to the Reorganization Plan No. 3 of 1970, effective December 2, 1970, this responsibility was transferred to the Radiation Office of the Environmental Protection Agency which was established by this reorganization.

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U.S. ENVIRONMENTAL PROTECTION AGENCY
Russell E. Train, Administrator

Reports

Environmental Radiation Effects of Nuclear Facilities in New York State

Michael S. Terpilak and Bruce L. Jorgensen[1]

The annual quantities and types of radioactive materials released from three operating nuclear electric generating facilities, a national laboratory, and a nuclear fuels reprocessing facility are presented and discussed. The period of interest spans the years 1969 through 1972 with some additional data for those facilities operating before 1969. Release quantities have been well controlled, considering the nature and vintage of the operations.

Results of environmental surveillance relying most heavily on the activities of the New York State Department of Environmental Conservation, are presented. Observations at Indian Point Station Unit No. 1 and at Nuclear Fuel Services have led to the discovery of several facility-related radioisotopes in environmental media. These two facilities are of comparatively early vintage, have produced slightly larger amounts of waste materials and have been the subject of more comprehensive studies than others in the State.

Dose consequences to hypothetical individuals and to populations within 50 miles of the facilities are addressed. It should be stressed that all individual doses presented are hypothetical. Doses via the drinking water and cow's milk pathways are particularly conservative. In each case, these hypothetical doses are at least an order of magnitude or more greater than the known worst case. No excessive exposure levels are known to have existed. All operations have resulted in postulated exposure levels well within applicable regulations or guidelines, generally being a small percentage of these values. Population doses have been surprisingly consistent through the period of interest. They are insignificant in comparison to the dose to the population of the State from natural or medical sources.

In most regions of the United States, the principal sources of environmental radiation are natural background and fallout from weapons tests. In the State of New York, however, three operational nuclear power facilities (*1–5*), one nuclear fuels reprocessing plant (*6*), two large research facilities, one Atomic Energy Commission national laboratory and numerous additional research, manufacturing, medical, and disposal facilities also contribute to environmental radiation.

Natural background and fallout data are monitored by the State Department of Environmental Conservation and the Environmental Protection Agency through the National Environmental Surveillance Networks. Environmental surveillance data concerning nuclear facilities are provided by the State Department of Environmental Conservation (*7–9*), the U.S. Atomic Energy Commission (AEC), nuclear facility operators, and special studies by interested parties.

This report deals with data from the environmental radiation surveillance programs in New York. It assesses the contributions that fixed facilities handling radioactive materials make to environmental radiation.

Solid wastes

Solid radioactive waste is generally removed from a nuclear facility site by a private contractor and is buried at an approved location in a manner such that there is expected to be no uncontrolled contribution of radioactivity to the environment from this source. New York has such a licensed burial facility in Cattaraugus County near the site of the fuels reprocessing plant. A compilation of the inventory of buried

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[1] **Environmental Protection Agency, Environmental Radiation Program, Region II, 26 Federal Plaza, New York, New York 10007.**

materials is given in table 1. A second AEC-licensed facility for the burial of high level wastes is also located at Nuclear Fuel Services (NFS). A compilation of the inventory of buried materials at this site is given in table 2 (*10*). A total of almost one million curies has been buried at these sites.

The State Department of Environmental Conservation (DEC) monitors (*7–9*) surface water samples from the vicinity of the burial sites to determine that significant migration out of the trenches or holes is not taking place (*4–6*). Analyses for the following nuclides have been made, with the noted results:

Cesium-137	None detected	1969–1972
Cobalt-60	None detected	1969–1972
Ruthenium-106	None detected	1969–1972
Zirconium-niobium-95	None detected	1971–1972
Cesium-134	Maximum of 20 pCi/liter in	1970
Manganese-54	None detected	1970–1972
Zinc-65	None detected	1970–1972
Strontium-89	Maximum of 7 pCi/liter in	1969
Strontium-90	Maximum of 15 pCi/liter in	1971
Gross beta[2]	Maximum of 228 pCi/liter in	1971 (4-year average, 25 pCi/liter)
Gross alpha	None detected	1971–1972
Tritium	Maximum of 21 650 pCi/liter in	1972 (4-year average, 4 990 pCi/liter)
Uranium	None detected	1969–1972

The DEC concludes that no significant surface discharges or underground seepages from the burial site have occurred. The origin of the minor discharges that have occurred is presently being investigated by the DEC in a cooperative effort with the New York State Atomic and Space Development Authority and the U.S. Environmental Protection Agency.

Major facilities and their surveillance programs

The distribution of major nuclear facilities in the State of New York is shown in figure 1.

A summary of the characteristics and locations of operating and scheduled nuclear-electric generating facilities in New York is given in table 3. A listing of other major nuclear facilities is given in table 4. Three nuclear power reactors were in operation during 1972; Indian Point Station Unit 1, Nine Mile Point Nuclear Station Unit 1, and R. E. Ginna Nuclear Power Plant Unit 1. Environmental surveillance programs for these nuclear-electric facilities in the State are summarized in table 5. Preoperational environmental surveillance programs and data for other electric generating facilities are also discussed.

Indian Point Station Unit 1

Indian Point Station Unit 1, located 25 miles north of New York City, owned and operated by Consolidated Edison Company, is on the Hudson River in the village of Buchanan, Westchester County. It was the first private nuclear power reactor in New York State, starting operations on September 16, 1962. This unit is a pressurized water reactor with a rated power of 285 megawatts electric. Condenser cooling water is withdrawn from and discharged to the Hudson River. Two villages, Verplanck and Buchanan, each with a population of less than 2100, are approximately 0.8 miles from the reactor. Peekskill, population 19 000, is approximately 2 miles northeast of the site. The estimated population within a 10-mile radius of the site is 160 000.

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[2] Exclusive of tritium.

Table 1. NFS low-level waste burial inventory

Trench number	Burial dates		Waste volume (cubic feet)	Percentage of volume by source						Byproduct material [g] (curies)	Plutonium-238 (curies)	Source material [h] (pounds)	Special nuclear material (grams)
	Start	Stop		(a)	(b)	(c)	(d)	(e)	(f)				
1	11/63	5/64	55 275	0.7	1.1	41.8	4.8	0	51.6	4 117	0	739	2 858
2	5/64	10/64	114 246	3.0	.2	24.0	53.0	0	19.2	2 215	0	553	659
3	7/64	11/65	198 675	5.2	.4	19.9	40.0	0	34.5	17 061	0.1	44 583	1 894
4	10/65	6/67	274 416	4.0	1.0	21.9	23.7	11.8	37.6	67 117	0	140 825	8 333
5	5/67	2/69	278 401	2.0	1.3	16.2	22.1	21.2	37.2	90 432	2 400	24 924	3 579
6	7/70	10/70	75	0	0	0	0	0	100.0	10 245	0	0	0
7	11/65	3/66	2 465	0	0	5.7	0	0	94.3	1 568	0	0	0
8	1/69	11/70	252 435	.6	2.0	16.0	24.6	25.2	31.6	34 757	3 914	321 226	13 074
9	10/70	6/71	173 722	1.6	1.5	9.0	14.0	18.7	55.2	27 323	6 835	43 777	4 550
10	6/71	5/72	182 462	5.8	2.9	8.5	15.5	84.4	33.0	39 887	15 006	101 614	3 139
11	5/72	12/72	182 769	6.8	1.5	10.2	31.3	15.1	35.0	46 704	6 827	80 092	6 151
Total			1 714 941							341 426	34 982	758 333	44 237
Average				2.7	1.1	15.7	20.9	11.5	48.1				

[a] Nuclear power plants.
[b] Institutional, educational and hospitals.
[c] Federal government.
[d] Industrial, pharmaceutical manufacturing, and research.
[e] NFS operations.
[f] Waste disposal and decontamination companies.
[g] Byproduct material percentage constituents: ^3H and ^{14}C, 46.4 percent = 158 420 Ci mixed fission products and miscellaneous, 31.0 percent = 105 840 Ci, ^{60}Co, 22.5 percent = 76 820 Ci, ^{137}Cs, ^{131}I, ^{133}I, ^{226}Ra, and ^{241}Am, 0.1 percent.
[h] Of total 758 333 pounds; 744 045 are uranium-238 and natural uranium with remainder thorium-232.

Liquid waste discharges

During normal plant operations, liquid waste from Indian Point Station Unit 1 is monitored for radionuclide content and is discharged at a controlled rate into the Hudson River through the cooling water discharge canal to assure compliance with technical specifications associated with the AEC operating license (*11*).

The quantities of radioactive liquid waste discharged from Indian Point Station Unit 1 are shown in table 6. The plant was shut down for refueling and repairs during much of 1970. The annual average doses given in this table are those that would be received internally by a hypothetical person consuming 100 g/day of fish from Green's Cove. There are no municipal drinking water intakes downstream of the Indian Point site.

Gaseous waste discharge

The radioactive gaseous wastes discharged from Indian Point Station Unit 1 are shown in table 7 (*3,11*). The average annual doses shown in this table are site boundary doses that would be received externally by the skin from radioactive noble gases and internally by the infant thyroid from iodine via milk consumption. Observed concentrations of particulates are lower than the MPC_{air} by a factor of approximately 100.

Environmental monitoring

Table 8 lists gross beta analyses of environmental samples (*7–9*) collected in the vicinity of Indian Point. The activity of onsite air particulate samples collected by Consolidated Edison varied from less than 0.1 pCi/m³ to 0.89 pCi/m³ in 1970 with the lower values in the winter and the higher values in the summer (*12*). Such variations are generally attributable to the seasonal transfer of radioactive fallout from the stratosphere.

The gross beta radioactivity in offsite particulate air samples, as indicated in table 8, varied from nondetectable to a maximum of 1.08 pCi/m³. No radioiodines have been identified in either onsite or offsite air samples. For the purpose of comparison, the gross beta activity in air particulate samples collected in Albany, Buffalo, and New York City by the

Table 2. NFS high-level burial site inventory summary [a]

Year	Number of holes	Total volume (cubic feet)	Total activity (curies)	MFP [b] (curies)	Zirconium-95 (curies)	Cobalt-60 (curies)	Mix [c] (curies)
1972	44	51 965	50 186	49 502	—	684	—
1971	27	8 125	373 663	98 705	223 075	51 883	0.05
1970	21	6 767	71 371	31	—	71 340	—
1969	20	7 821	25 862	10	—	25 852	.018
1968	17	7 146	2 669	25	46	2 598	—
1967	17	4 718	21 723	525	33	21 052	113
1966	5	1 236	534	24	2	0.109	508
Total	151	87 778	546 008	148 822	223 156	173 409	621

[a] Total curies buried at NFS: 376 408 at low-level site, 546 008 in high-level holes, 922 416 total.
[b] MFP—mixed fission products.
[c] Mix—mixed radionuclides (unidentified).

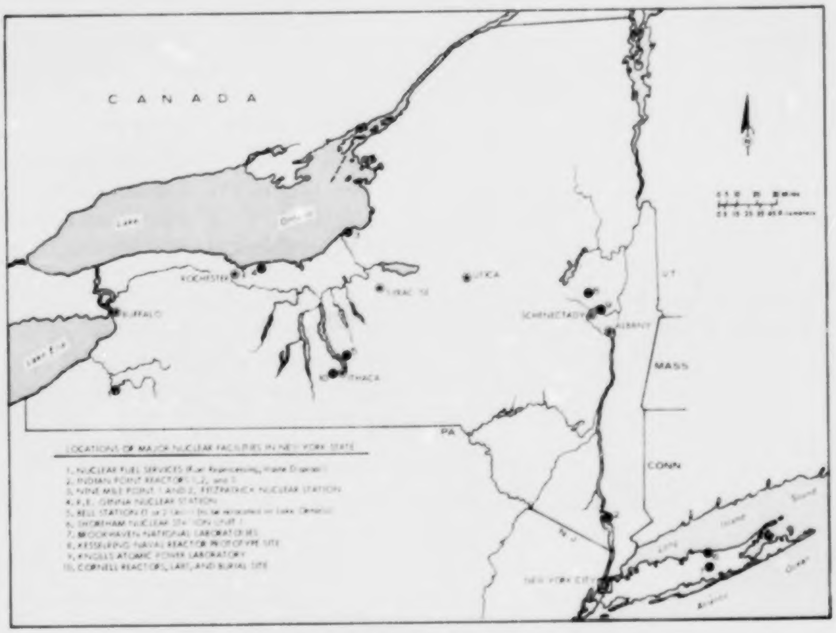
CANADA
Lake Ontario
Lake Erie
ROCHESTER
BUFFALO
SYRACUSE
UTICA
SCHENECTADY
ALBANY
ITHACA
VT
MASS
CONN
PA
N.J.
NEW YORK CITY
Long Island Sound
Ocean
Atlantic
LOCATIONS OF MAJOR NUCLEAR FACILITIES IN NEW YORK STATE
1. NUCLEAR FUEL SERVICES (Fuel Reprocessing, Waste Disposal)
2. INDIAN POINT REACTORS 1, 2, and 3
3. NINE MILE POINT 1 AND 2, FITZPATRICK NUCLEAR STATION
4. R.E. GINNA NUCLEAR STATION
5. BELL STATION (1 or 2 Units) (to be relocated on Lake Ontario)
6. SHOREHAM NUCLEAR STATION UNIT 1
7. BROOKHAVEN NATIONAL LABORATORIES
8. KESSELRING NAVAL REACTOR PROTOTYPE SITE
9. KNOLLS ATOMIC POWER LABORATORY
10. CORNELL REACTORS, LAB, AND BURIAL SITE

Figure 1. Major nuclear facilities in New York State

Radiation Alert Network varied typically from nondetectable to 1 pCi/m^3.

The gross beta radioactivity in water samples taken offsite varied from nondetectable to a maximum of 183 pCi/liter. Data from Albany County, which was used as a background sample, varied from nondetectable to 11 pCi/liter in the years 1970 through 1972 (*7–9*). According to the Department of Environmental Conservation, "Samples of water from the lower Hudson River show higher gross beta results because of the effect of naturally occurring potassium-40 and the intrusion of saltwater up the river" (*7*).

Figure 2 shows the locations of the environmental sampling stations in relation to the plant (*13*).

The data in tables 6 and 7 have limited quantitative value for the purpose of evaluating the exposure to the general population resulting

Table 3. Characteristics of nuclear electric generating facilities in New York State

Facility	Owner	Reactor type [a]	Power level		Year of startup	Location	Approximate population within 10 miles [b]
			MW(e)	MW(t) net			
Indian Point Station Unit 1	Consolidated Edison Company	PWR	265	615	1962	Indian Point	160 000
Indian Point Station Unit 2	Consolidated Edison Company	PWR	873	2 758	1973	Indian Point	160 000
Indian Point Station Unit 3	Consolidated Edison Company	PWR	965	3 025	1975	Indian Point	
Nine Mile Point Nuclear Station Unit 1.	Niagara Mohawk Power Corporation.	BWR	610	1 850	1969	Scriba	31 000
Nine Mile Point Nuclear Station Unit 2.	Niagara Mohawk Power Corporation.	BWR	1 150	3 223	1978	Scriba	
James A. Fitzpatrick Nuclear Power Station	Power Authority [c] of State of N.Y.	BWR	848	2 436	1974	Scriba	31 000
R. E. Ginna Nuclear Power Plant Unit 1.	Rochester Gas and Electric Company	PWR	420	1 300	1969	Rochester (Ontario, N.Y.)	27 000
Shoreham Nuclear Power Station	Long Island Lighting Company	BWR	849	2 436	1977	Brookhaven	
Bell Station	NYS Electric and Gas Company	BWR	866	2 436	1980's	Lake Ontario	
Total	6 Companies	9 Power Plants	6 846	20 079		5 locations	

[a] BWR, boiling water reactor.
PWR, pressurized water reactor.

[b] Operating facilities only.

[c] To be operated by Niagara Mohawk Power Corporation under contract.

Table 4. Major nuclear facilities in New York State other than nuclear power generating facilities

Facility	Location	Startup date	Type of operation
Nuclear Fuel Services, Inc:	West Valley, Cattaraugus County, N.Y.	1966	Nuclear fuel reprocessing plant storage of high level waste fission products
	Burial site West Valley Cattaraugus County, N.Y.	1963	Solid radioactive wastes shipped mainly from facilities in Northeast States buried in trenches
Brookhaven National Laboratory:	Upton, Suffolk County, N.Y.	1951	Testing and research reactors, (HFBR), (MRR)
Knolls Atomic Power Laboratory:	West Milton, Saratoga County, N.Y.	1955	Testing and research reactors
Knolls Atomic Power Laboratory, Knolls site, General Electric Company:	Schenectady, Schenectady County, N.Y.	1949	Testing and research reactor
Cornell Nuclear Reactor Laboratory, Cornell University:	Ithaca, Tompkins County, N.Y	1962	Research and training reactors-(TRIGA MARK II), (ZPR)
Western New York Nuclear Research Center, University of Buffalo:	Buffalo, Erie County, N.Y	1961	Research reactor-(PULSTAR)
United Nuclear Corporation Remote Experimental Station:	Pawling, Dutchess County, N.Y.	1961	Heavy water nuclear reactor 5 watts thermal (PRR) (abandoned 3/74)
Union Carbide Corporation, Sterling Forest Research Center:	Sterling Forest, Orange County, N.Y.	1961	5MW pool type, light water research reactor (UCNR), produces pharmaceutical radioisotopes
Cornell burial site:	Lansing, Tompkins County, N.Y.	1960	Burial of waste from numerous research projects on campus
National Lead Company, Nuclear Metals Division:	Albany, Albany County, N.Y	1960	Fabrication of depleted uranium counter weights, some fabrication of uranium fuel elements

from liquid and gaseous releases from a nuclear facility (*14*). However, they might be useful for indicating when new injections of radioactivity into the environment, thus serving as a basis for further investigation by more detailed radionuclide analysis.

Such radionuclide analyses are made by the State Department of Health for the Department of Environmental Conservation (*7–9*). A summary of results of some of these analyses for aquatic vegetation, and silt is contained in tables 9, 10, and 11. Some results of the opera-

Table 5. Environmental radiation surveillance programs in New York State

Media	Indian Point Station			R. E. Ginna Nuclear Power Station			Nine Mile Point Nuclear Station		
	Number of locations	Frequency of collection	Type of analysis	Number of locations	Frequency of collection	Type of analysis	Number of locations	Frequency of collection	Type of analysis
Airborne halogens:							11	Weekly	Gamma spectrum analysis
Air particulates + organic iodides:	5 with 3 other locations for 1 wk consecutively	Weekly	Gross beta, gamma scan				11	Weekly Monthly	Gross beta, gamma scan
External radiation: (direct)	Along principal roads within 5-mile radius	Annually	Gamma background						
	Selected locations	Monthly	Gamma background						
Gamma radiation monitors:							6	Continuous	Gross gamma
Fallout:	2	Monthly	Gross beta, tritium						
Precipitation:							11	Monthly	Gross beta, gamma scan
Milk:					Monthly grab	Gross beta	Adjacent dairy	Monthly	^{131}I, gross beta, ^{90}Sr
Surface water					Monthly	Gross beta			
River water	2	Weekly	Gross beta, tritium on monthly composite						
Lake water	3	Monthly grab	Gross beta, tritium	2	Weekly	Gross beta	Downstream of effluent discharge	Weekly	Gross beta, gamma scan
Creek water:					Monthly grab	Gross beta			
Reservoir water: (Deer Creek)	3	Monthly grab	Gross beta, tritium						
Well water:	3	Monthly grab	Gross beta, tritium		Monthly grab	Gross beta			
Bottom sediment:	5	Spring, summer, fall	Gross beta, gamma scan		Annually	Gross beta			
Soil:	5	Annually	Gross beta, gamma scan						
River aquatic vegetation:	5	Spring, summer, fall	Gross beta, gamma scan						
Lake aquatic vegetation:	3	Spring, summer, fall	Gross beta, tritium						
Vegetation:	5	Spring, summer, fall	Gross beta, gamma scan						
Clams:							2	Spring, fall	Gross beta, gamma scan, ^{90}Sr
Fish:	Where available	Monthly	Gross beta, gamma scan		Quarterly	Gross beta	2	Spring, fall	Gross beta, ^{90}Sr
Gammarus: (fresh-water shrimp)							2	Spring, fall	Gross beta, gamma scan, ^{90}Sr
Film badges or TLD'S:							11	Monthly	Gross gamma
Human bone:							2	Spring, fall	Gross beta, gamma scan, ^{90}Sr

See footnotes at end of table.

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Table 5. Environmental radiation surveillance programs in New York State—continued

Media	New York State			Nuclear Fuel Services			Atomic Energy Commission		
	Number of locations	Frequency of collection	Type of analysis	Number of locations	Frequency of collection	Type of analysis	Number of locations	Frequency of collection	Type of analysis
Air:	16	Varies	Gross beta, ^{85}Kr around NFS	4	1 daily 3 weekly	^{85}Kr, gross alpha, gross beta	1 2 3	Daily Weekly Monthly	Gross alpha, gross beta Gross alpha (monthly HTO)
External radiation: (direct)							6	Monthly	Gross gamma
Milk:	31	Varies	Gross beta, ^{131}I, ^{137}Cs, ^{140}Ba, ^{40}K, ^{89}Sr, ^{90}Sr, ^{3}H, other gammas	4 2	Weekly Annual	^{129}I, ^{90}Sr, ^{131}I, ^{134}Cs, ^{137}Cs	2	Quarterly	Gamma-spectrum + iodine-131-separation
Algae or vegetation:	9	2/a	Gamma scan				11	Yearly	Gamma spectrum
Fish:	12	2/a	Gamma scan (^{89}Sr, ^{90}Sr around Con Ed)	1	2/a	Bone—^{90}Sr, Flesh—^{134}Cs, ^{137}Cs, ^{90}Sr	3	Yearly	Gamma spectrum
Deer:	4–5	2/a	^{90}Sr, ^{129}I,[a] Pu gamma in lung	1	Annual	Bone—^{89}Sr, ^{90}Sr, Flesh—^{134}Cs, ^{137}Cs, ^{90}Sr			
Soil:							10	Semiannual	Gamma spectrum
Bottom sediment:	5	2/a	Gamma scan				11	Yearly	Gamma spectrum
Silt:				1	Quarterly	Gross beta, gross alpha, gamma scan			
Precipitation:		After each rain	^{89}Sr, ^{90}Sr		Monthly	Tritium		After each rain Monthly composite	Gross alpha, gross beta HTO, ^{90}Sr, gamma spectrum
Surface water:	37	Varies—monthly or weekly	Gross beta (^{3}H, ^{89}Sr, ^{90}Sr on selected samples)	6	Varies—quarterly, monthly, or weekly	Varies—gross alpha, gross beta, ^{3}H, ^{106}Ru, (^{129}I), ^{134}Cs, ^{137}Cs, ^{89}Sr, ^{90}Sr, U isotopic, Pu isotopic	10	Monthly grab	Gross alpha, gross beta, HTO
Public water supply:	21	Varies	Gross beta (^{3}H, ^{89}Sr, ^{90}Sr on selected samples)						
Ground water:	8	Annually	Gross beta, tritium				16	Monthly	Gross alpha, gross beta, HTO [^{90}Sr, gamma spectrum (quarterly)]
							34	Quarterly	Gross alpha, gross beta, HTO [^{90}Sr, gamma spectrum (semiannually)]
							26	Semiannual	Gross alpha, gross beta, HTO [^{90}Sr, gamma spectrum (annual)]
Fallout [b]:	2	Weekly	^{89}Sr, ^{90}Sr, ^{3}H, gamma scan		Monthly	Gross alpha Gross beta			

[a] Program around Nuclear Fuel Services only.
[b] Denotes radioactive material originating from atmosphere and settling or being washed into a bucket.
[c] Calculated based on dilution.

Table 6. Quantities of radioactive liquid waste discharged by the Indian Point Station 1 [a]

Year	Mixed fission and corrosion products				Tritium		
	Curies released	MPC [b] (pCi/liter)	Annual average percent MPC	Annual dose [c] (mrem)	Curies released	Annual average percent MPC	Annual dose [c] (mrem)
1962–1968	146 (21/yr avg)	7000	0.22 to 70.1	0.50 (average)	1210	0.058 (1968 percent MPC)	0.02 (1968 dose)
1969	28	7000	1.01	.60	1100	.08	.02
1970	7.8	7000	.28	.20	410	.03	<.01
1971	81	7000	2.91	.95	725	.053	.01
1972	25.4	7000	.91	.64	574	.04	.02
Projected future	40.0	7000	1.44	<1.0	1500	.11	.55

[a] All curie released data from final EIS Unit 2, Section III except 1972 data, 1972 data from reference *3*.
[b] The technical specifications require a more restrictive 1000 pCi/liter.
[c] For consumption of 100 g/day of fish from Green's Cove.

Table 7. Radioactive gaseous waste discharged by the Indian Point Station Unit 1

Year	Noble and activation gases				Halogens and particulates			
	Released (curies)	Permissible (curies)	Percent of permissible	Annual average dose [a] (mrem)	Released (curies)	Permissible (curies))	Percent of permissible	Annual average dose [a] (mrem)
1963–1968 [b]	166	3.2×10^7	0.001	0.005	([c])	45.6	—	—
1969	600	5.3×10^6	.01	.05	0.025	7.6	0.33	1.7
1970 [d]	1800	5.3×10^6	.03	.15	.075	7.6	1.0	5
1971 [d]	380	5.3×10^6	.007	.02	.21	7.6	2.8	14
1972 [e]	543	5.3×10^6	.009	.04	.928	7.6	12.4	62
Projected future maximum	1200	5.3×10^6	.02	.10	.37	7.6	4.9	25

[a] At plant perimeter.
[b] 1963–68 data from reference *4*.
[c] Negligible.
[d] 1969–71 curies released data from final EIS Unit 2, Section III, (*11*).
[e] 1972 data from reference *3*.

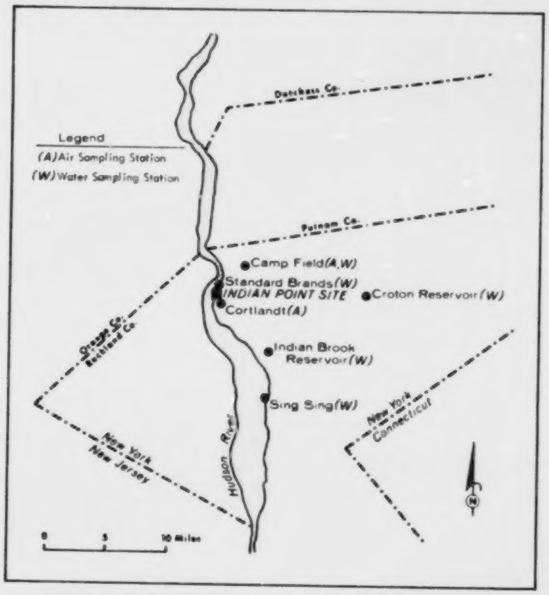
Dutchess Co.
Legend
(A) Air Sampling Station
(W) Water Sampling Station
Putnam Co.
Camp Field (A,W)
Standard Brands (W)
INDIAN POINT SITE
Croton Reservoir (W)
Cortlandt (A)
Orange Co.
Rockland Co.
Indian Brook Reservoir (W)
Sing Sing (W)
New York
Connecticut
New York
New Jersey
Hudson River
N
0
5
10 Miles

Figure 2. Environmental sampling locations Indian Point Station

tion of Indian Point Station Unit 1 can be seen in these tables.

The higher levels of cesium-134 and cesium-137 observed in fish and aquatic vegetation collected from Green's Cove can be attributed to liquid releases from Indian Point Station Unit 1 (*15*). High levels of cobalt-60 and manganese-54 observed in aquatic vegetation from Green's Cove and Tappan Zee Bridge in comparison to the other two sampling stations are attributed to releases from the Indian Point Station. The nuclides, cesium-137, ruthenium-106, and zirconium-niobium-95, are characteristic of fallout from weapons testing.

A concentration of 100 pCi/kg in fish flesh, (assuming 50 pCi/kg each of cesium-134 and cesium-137) would result in an annual whole body dose of 0.18 mrem if consumed at a rate of 100 g/day (*16*).

An "Environmental and Postoperational Survey for Radioactivity-Consolidated Edison Indian Point Reactors" (*13*) conducted by the

Table 8. Offsite gross beta radioactivity levels in air and water, Indian Point Station, 1968-1972

Station location		1968[a]	1969[a]	1970[a]	1971[b]	1972[c]
Air particulate concentrations: (pCi/m^3)						
Peekskill:						
Camp Field Filter Plant:	Average	0.15	0.20	0.22	0.33	0.11
	Maximum	.49	.56	.46	[illegible]	.33
	Minimum	.10	.02	.04	.06	.02
Cortlandt:						
Department of Public Works:	Average	.10	.11	.27	.23	.09
	Maximum	.26	.33	.70	.73	.39
	Minimum	.01	ND	.05	.03	.02
Water concentrations: (pCi/liter)						
Peekskill:						
Hudson River at Standard Brands:	Average	17	9	14	12	8
	Maximum	52	32	37	183	57
	Minimum	4	ND	ND	ND	ND
Camp Field Reservoir:	Average	3	3	7	7	3
	Maximum	10	15	31	38	5
	Minimum	ND	ND	ND	ND	2
Yorktown:						
Croton Reservoir:	Average	4	4	10	5	4
	Maximum	5	6	80	28	8
	Minimum	1	ND	3	ND	2
Ossining:						
Hudson River at Sing Sing:	Average	25	23	29	20	15
	Maximum	117	71	68	65	68
	Minimum	4	ND	ND	ND	ND
Indian Brook Reservoir:	Average	5	4	6	3	4
	Maximum	7	7	13	7	5
	Minimum	4	ND	3	ND	3

[a] 1968–1970 data—reference *8*.
[b] 1971 data—reference *2*.
[c] 1972 data—reference *3*.
ND, nondetectable, below minimum detectable activity.

New York State Department of Environmental Conservation reports the results of a pressurized ionization chamber background survey for gamma radiation in the vicinity of Indian Point Station. The results of this survey are given in table 12. This table includes the average reading for all stations for 1964 through 1970. In general, it can be concluded that no significant or measurable increase in background gamma radiation occurred during those years of reactor operation. Figure 3 gives the locations of the ionization chamber stations used for this survey.

Pressurized ionization chamber readings of penetrating radiation in the vicinity of the plant, which were taken by the State DEC (*7–9*), gave the following average hourly exposure rates:

1970: 9.8 μR/h
1971: 8.3 μR/h
1972: 8.7 μR/h

Nine Mile Point Nuclear Station Unit 1

Nine Mile Point Nuclear Station Unit 1 is a boiling water reactor with a rated capacity of 1850 MW(t). It is located on the southeast shore of Lake Ontario in the town (township) of Scriba, which has a population of 1400 and Oswego County, which has a population of 23 800. The nearest large city is Syracuse (population 197 300) located 36 miles southeast of the plant. The area in which the plant is located is used primarily for residential and agricultural purposes. Test operations were conducted during the period from late 1969 to March 2, 1970. A long shutdown for maintenance and repairs ended on July 11, 1970. Since July 12, 1970 full power operations have been carried out, subject to maintenance and refueling outages.

Table 9. Radioactivity in algae and/or aquatic vegetation in Lower Hudson

Station	Location from plant	Year	Number of samples	Average concentration[a] (pCi/kg wet weight)						^{40}K (g/kg)
				^{137}Cs	^{60}Co	^{106}Ru	^{95}Zr-Nb	^{54}Mn	^{134}Cs	
Green's Cove	2 miles S	1970	2	292	690	873	333	3751	—	—
		1971	2	811	614	2550	2398	6797	817	4.50
		1972	2	178	43	272	172	263	ND	—
Tappan Zee Bridge, west	14 miles S	1970	2	46	126	335	342	778	—	—
		1971	2	190	146	914	275	1543	—	—
		1972	2	57	70	ND	121	715	—	—
Iona Island	3 miles NW	1970	2	193	61	578	700	341	—	—
		1971	2	289	44	2883	1646	749	56	4.06
		1972	2	128	31	229	150	214	—	—
Peekskill Bay	1.5 miles N	1970	2	189	149	494	799	687	—	—
		1971	2	321	194	ND	120	2422	17	3.73
		1972	2	115	65	154	108	455	—	—

[a] Nondetectable quantities have been considered as 0 pCi/kg for averaging purposes.
ND, nondetectable.
—, no analysis.

Table 10. Radioactivity in fish in the Lower Hudson

Station	Location from plant	Year	Number of samples	Average concentration [a] (pCi/kg wet weight)								
				^{137}Cs	^{60}Co	^{106}Ru	^{95}Zr-Nb	^{134}Cs	^{89}Sr	^{90}Sr	^{65}Zn	^{54}Mn
Green's Cove	2 miles S	1970	3	55	ND	ND	ND	54	—	71	—	70
		1971 [b]	2	286	ND	ND	—	203	ND	140	ND	—
		1972	3	159	ND	ND	—	214	ND	190	—	—
Tappan Zee Bridge, west	14 miles S	1970	2	53	ND	ND	—	33	—	—	—	—
		1971 [b]	2	157	ND	ND	—	149	17	120	ND	—
		1972	2	181	ND	ND	—	84	ND	45	—	—
Iona Island	3 miles NW	1970	2	52	ND	ND	—	15	66	41	—	—
		1971 [b]	3	123	ND	ND	—	56	ND	207	ND	—
		1972	3	159	ND	ND	—	62	ND	34	—	—
Peekskill Bay	1.5 miles N	1970	2	51	ND	ND	—	35	—	90	—	—
		1971 [b]	2	373	ND	ND	—	225	ND	200	ND	—
		1972	3	165	ND	ND	—	80	ND	41	—	—

[a] Nondetectable quantities have been considered as 0 pCi/kg for averaging purposes.
[b] 1971 figures are averaged for flesh and bone composite.
ND, nondetectable.
—, no analysis.

Table 11. Radioactivity in silt in the Lower Hudson River

Station	Location from plant	Year	Number of samples	Average concentration [a] (pCi/kg wet weight)		
				Cesium-137	Cobalt-60	Cesium-134
Green's Cove	2 miles S	1970	2	51	—	—
		1971	2	514	124	441
		1972	—	—	—	—
Tappan Zee Bridge, west	14 miles S	1970	2	41	—	—
		1971	2	892	95	502
		1972	—	—	—	—
Iona Island	3 miles NW	1970	2	25	—	—
		1971	2	385	52	189
		1972	—	—	—	—
Peekskill Bay	1.5 miles N	1970	2	ND	—	—
		1971	2	211	33	119
		1972	—	—	—	—

[a] Nondetectable quantities have been considered as 0 pCi/kg for averaging purposes.
ND, nondetectable.
—, no analysis.

Table 12. Pressurized ionization chamber gamma background survey

Site	Township	1967 (μR/h)	1968 (μR/h)	1969 (μR/h)	1970 (μR/h)
1	Cortlandt	8.8	—	—	9.7
2	Cortlandt	9.2	8.6	8.8	9.5
3	Cortlandt	8.8	7.9	12.4	12.3
4	Cortlandt	10.4	9.8	10.6	10.1
5	Highlands	8.8	9.3	8.5	9.3
6	Cortlandt	9.2	8.9	9.6	8.6
7	Yorktown	9.6	10.1	9.2	10.4
8	Cortlandt	9.2	10.4	9.4	9.6
9	Stony Point	9.2	9.3	8.1	9.1
10	Haverstraw	9.6	10.4	9.2	9.2
11	Clarkstown	8.4	9.4	8.9	8.9
12	Mt. Pleasant	9.2	10.8	10.1	10.1
13	Yorktown	8.1	9.2	8.9	10.1
14	Somers	6.9	8.8	7.7	8.9
15	Kent	9.6	8.5	10.7	10.8
16	Greenburgh	8.4	9.3	9.1	8.6
17	Harrison	9.2	8.9	9.8	9.8
18	Poundridge	9.6	10.1	10.2	11.2
19	North Salem	8.1	—	9.1	10.0

Average reading for all stations near Indian Point Station by year (μR/h)

1964	1965	1967	1968	1969	1970
11.3	10.0	9.0	9.4	9.5	9.8

Liquid waste discharges

Liquid waste from Nine Mile Point Nuclear Station Unit 1 is collected in storage tanks and disposed into Lake Ontario in batches. Discharge is on a daily basis at a controlled rate dependent upon gross beta activity concentrations. The liquid effluent is discharged via the condenser cooling water discharge, which provides dilution. The quantities of radioactive liquid waste discharged by this plant during the years 1969–72 are given in table 13. The composition of a typical batch of radioactive liquid waste is given in table 14.

Gaseous waste discharges

Noncondensible gases generated in the processes of operation of the Nine Mile Point Nuclear Station Unit 1 plant are discharged to the off-gas system by the air ejector. Wastes from this source are held up 30 minutes in order to allow time for the decay of short-lived isotopes. This waste is then discharged to the atmosphere through a stack, 350 feet high. Capability is provided in the system for automatic shutdown in the event that radioactivity release rates exceed a preset limit. The total gaseous activity discharged (*2,17*) and the calculated potential annual dose rates are shown in table 15. A typical isotopic analysis of stack releases is given in table 16 (*17*).

Table 13. Quantities of radioactive liquid waste discharged by the Nine Mile Point Nuclear Station Unit 1

Year [a]	Mixed fission and corrosion products			Tritium		
	Curies released	Annual average concentration (pCi/liter)	Annual average percent limit [b]	Curies released	Annual average percent MPC in discharge canal	Annual average dose from tritium [c] (mrem)
1969	0.90	1.69	1.7	<1	$<10^{-4}$	Negligible
1970	28.0	52.5	52.5	20	1.5×10^{-3}	.006
1971	32.2	60.4	60.4	12.4	9×10^{-4}	.003
1972	34.5	64.6	64.6	28	2.1×10^{-3}	.008
Projected future	2.0	3.75	3.75	20	1.5×10^{-3}	.006

[a] All curies released data except 1972 from reference *2*. 1972 and projected future data from draft EIS, reference *17*.

[b] MPC is 100 pCi/liter for unidentified radionuclide mix while technical specifications allow 3300 pCi/liter if isotopic analysis is done.

[c] At plant perimeter, for ingestion of discharge canal water (*16*).

Table 14. Composition of a typical batch of liquid radioactive waste, Nine Mile Point Nuclear Station Unit 1[a]

Isotope	Half life	Percent in typical batch	Average concentration in discharge canal (pCi/liter)	Percent of MPC
Cobalt-60	5.3 yr	9.5	3.5	0.007
Cobalt-58	71.3 d	15.2	5.6	.006
Chromium-51	27.8 d	60.0	23	.001
Manganese-54	303.0 d	5.9	2.3	.002
Iodine-131	8.0 d	.4	.17	.060
Iron-59	45.0 d	9.0	3.3	.007
Total	....	100	38	0.083

[a] Normalized to 20 Ci/yr discharge.

Environmental monitoring

Environmental samples taken in the vicinity of the Nine Mile Point Nuclear Station Unit 1 are analyzed for some specific radionuclides and for gross beta (*7–9*). Table 17 gives the results of gross beta analyses of air and water samples. The results are not remarkable. The concentrations in air particulates at the background station in Albany are within the previously mentioned range of nondetectable to 1.08 pCi/m^3. This is true for onsite and offsite samples. The results of water sample analysis are typical for freshwater where the potassium-40 contribution is less significant than in saline water. Again, they fall within the range of background samples taken at Albany which have previously been stated to range from nondetectable to 11 pCi/liter.

Specific radionuclide analyses have not been carried out around the Nine Mile Point Nuclear Station plant to the extent which they are carried out in the vicinity of Indian Point Station. Those samples which have been analyzed include onions and apples from the area (1970), aquatic vegetation and mud from Lake Ontario near the plant (1970) and fish taken near the plant (1971).

Table 15. Release to gaseous effluents from Nine Mile Point Nuclear Station

Year [a]	Noble gases				Halogens and particulates			
	Releases (curies)	Permissible (curies)	Percent of permissible	Annual dose (mrem) from immersion [c]	Releases (curies)	Permissible [b] (curies)	Percent of permissible	Annual average dose (mrem) to infant thyroid [c]
1969	60	2.6×10^7	Negligible	Negligible	<0.001	47.3	Negligible	Negligible
1970	9 500	2.6×10^7	0.04	0.20	<.06	47.3	0.1	0.50
1971	253 000	2.6×10^7	.97	5.3	.78	47.3	1.65	7.5
1972	520 000	2.6×10^7	2.0	10.9	.95	47.3	2.01	9.1
Projected future	11 000	2.6×10^7	.05	.23	.56	47.3	1.18	5.4

[a] Annual releases (except 1972) from reference *2*, 1972, and projected future from draft EIS reference *17*.

[b] Permissible limit for multiple release points derived from curies released and sum of percentages of permissible from points of release, see also reference *1*.

[c] Doses are for continuous occupation at worst site location and are hypothetical; representation of a real dose is not intended.

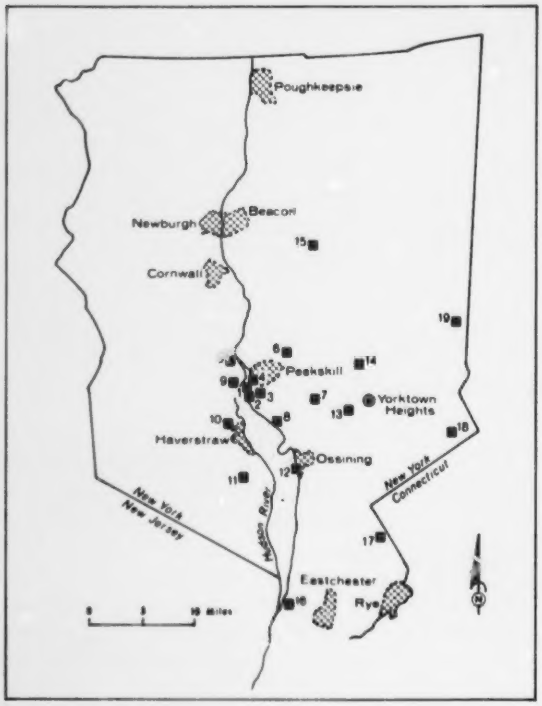

Figure 3. Location of stations for pressurized ionization chamber gamma survey

Table 16. Radionuclides in stack discharges, Nine Mile Point Nuclear Station Unit 1

Isotope	Percent total	Discharge rate (μCi/s)[a]
Xenon-138	10.9	860
Krypton-87	18.9	1 490
Krypton-88	16.0	1 260
Krypton-85m	5.5	436
Xenon-135	24.0	1 890
Xenon-133	23.3	1 835
Nitrogen-13	1.4	115
Total	100	7 886

[a] Normalized to 250 000 Ci/yr at 100 percent service availability.

Table 17. Radioactivity levels in air particulates and water (gross beta), Nine Mile Point Nuclear Station Unit 1

Station location		1970[a]	1971[a]	1972[a]
Air particulates (pCi/m³):				
Onsite, 3 stations:	Average	0.19		
	Maximum	.69		
	Minimum	ND		
Scriba:	Average	.12	0.20	0.05
	Maximum	.37	.69	.14
	Minimum	.01	.02	ND
Water concentrations (pCi/liter):				
Oswego City Hall tap, Lake Ontario water	Average	4	4	4
	Maximum	5	5	6
	Minimum	3	3	ND
New Haven, Dempster Lake Road, Lake Ontario water.	Average	5	5	5
	Maximum	8	6	6
	Minimum	4	3	4

[a] References 7, 8, and 9, respectively, for 1970–1972 data on offsite stations.

Small amounts of cesium-137 (28 pCi/kg in one sample) and of strontium-90 (42 pCi/kg in one sample) were observed in apples. The analysis of onion samples indicated small quantities of zirconium-niobium-95 (21 pCi/kg in one sample) and strontium-90 (40 pCi/kg in one sample). These data are insufficient to allow conclusions to be drawn.

Mud samples taken from Dempster Beach showed some cesium-137 (214 and 12 pCi/kg in two samples), ruthenium-106 (203 pCi/kg in one sample) and cesium-134 (41 pCi/kg in one sample). As mentioned previously, cesium-137 and ruthenium-106 are characteristic of weap-

Table 18. Radioactivity in aquatic samples, Nine Mile Point Nuclear Station Unit 1 (pCi/kg)

Sample type	Year		Radionuclide Concentration (pCi/kg wet weight)							
			^{137}Cs	^{60}Co	^{134}Cs	^{65}Zn	^{90}Sr	Gross beta	Gross gamma	^{95}Zr-Nb
Fish:	(Preop) 1969	Maximum	132	14	—	76	510	870	565	
		Minimum	ND	ND	—	ND	76	364	188	
	1970	Maximum	6 190	[a] 630	—	ND	3 160	4 100	7 300	
		Minimum	ND	ND	—	ND	110	—	300	
	1971	Maximum	542	ND	71	ND	[b] 589 (18)	—	—	
		Minimum	190	ND	ND	ND	[b] 433 (3)	—	—	
	1972	Maximum	1 060	90	350	—	[b] (66)	—	—	
		Minimum	206	ND	ND	—	[b] (9)	—	—	
Algae:	(Preop) 1969	Maximum	200	30	—	70	2 410	13	35 600	—
		Minimum	—	—	—	—	—	—	—	—
	1970	Maximum	1 140	15 400	—	ND	—	18 100	35 000	—
		Minimum	ND	1 180	—	ND	150	1 710	—	—
	1971	Maximum	269	19	—	—	—	—	—	994
		Minimum	66	ND	—	—	—	—	—	958
	1972	Maximum	—	—	—	—	—	—	—	—
		Minimum	—	—	—	—	—	—	—	—

[a] This was the only 1 of 13 samples showing any detectable cobalt-60; it may therefore be suspect.
[b] Numbers in parenthesis are for flesh—others are for bone.
ND, nondectectable, below minimum detectable activity.

15

ons testing fallout. The observed level of cesium-134 is low and no conclusion as to its possible source would be justified.

An aquatic sampling program was conducted around the facility by Eberline Instrument Corporation in 1969 and 1970. Some of the results of that program and more recent results of analysis by the State are given in table 18. Some increases in concentrations of nuclides are evident after 1969, but the extraction of data from different sources and the lack of knowledge concerning how to interrelate information from different analysists makes it difficult to draw further conclusions. The capability of algae to significantly concentrate cobalt-60 is evidenced by this table.

The State DEC reports the following average hourly exposure rates (taken from PIC readings) in the vicinity of the Nine Mile Point Nuclear Station Unit 1 (*7–9*):

1970: 8.1 μR/h
1971: 7.6 μR/h
1972: 7.4 μR/h

R. E. Ginna Nuclear Power Plant

The R. E. Ginna Nuclear Power Plant is located in Brookwood, Wayne County, New York. The site, consisting of 338 acres, is 16 miles east of Rochester, N.Y., which has a population of approximately 500 000. This is a pressurized water reactor rated at 1300 MW(t). The region adjacent to the site is agricultural, with open, rolling terrain. The predominant wind direction is away from Rochester over Lake Ontario (*18*).

Initial criticality was attained in November 1969 and testing continued until May 1970. Since that time the plant has routinely been used for power production except for maintenance and refueling outages. A 17 percent derating occurred in portions of 1972 and 1973 as a result of the identification of unpressurized fuel cladding collapes in Ginna fuel.

Liquid waste discharges

Liquid radioactive wastes from the Ginna plant are discharged at controlled rates to Lake

Table 19. Quantities of radioactive liquid waste discharged by the R. E. Ginna Nuclear Power Plant

Year	Mixed fission and corrosion products				Tritium		
	Curies released [a]	MPC [a] (pCi/liter)	Annual average percent MPC	Annual average dose [b] (mrem)	Curies released [a]	Annual average percent MPC	Annual average dose [b] (mrem)
1969	0.02	300	0.01	0.05	<1	Negligible	Negligible
1970	10.0	300	5	25	110	5×10^{-3}	0.03
1971	.96	300	.5	2.5	154	7×10^{-3}	.04
1972	.375	300	.18	9	117	5×10^{-3}	.03
Projected future	.9	300	.5	2.5	<1000	$<5\times10^{-2}$	<.3

[a] All curies released data from references *2* and *3*, projected future from draft environmental impact statement reference *29*.
[b] For consumption of discharge canal water.

Table 20. Release of gaseous effluents from R. E. Ginna Nuclear Power Plant

Year	Noble and activation gases				Halogens and particulates			
	Releases (curies)	Permissible (curies)	Percent of permissible	Dose [a] (mrem)	Releases (curies)	Permissible (curies)	Percent of permissible	Dose [a] (mrem)
1969	<1	3.6×10^{5}	Negligible	Negligible	0.001	1.7	Negligible	Negligible
1970	10 000	3.6×10^{5}	2.8	5.7	.05	1.7	3.0	15
1971	31 800	3.6×10^{5}	8.9	18.2	.17	1.7	10.0	51
1972	11 800	1.7×10^{5}	6.9	7.0	.035	.9	3.8	11
Projected future	2 350	1.7×10^{5}	1.4	1.4	.11	.9	12.2	33

[a] Noble gas dose, continuous immersion at site boundary skin dose; halogen dose, infant thyroid dose from boundary milk ingestion. Annual releases, except 1972, from reference *2*, 1972 data, *3*.

Ontario, using the once-through-cooling discharge water flow for dilution. The quantities of radioactive materials released in liquid wastes from the Ginna nuclear plant are given in table 19. This plant is notable for its control to the point of virtual elimination of primary-to-secondary leakage and the associated escape of some primary coolant activity into the environment.

Gaseous waste discharges

The off-gases from the reactor coolant make up most of the gaseous radioactive wastes associated with this facility. These gases are held up for at least 30 minutes in order to allow time for decay of radioisotopes with short half lives. The waste is discharged to the atmosphere through various building vents. The total gaseous activity discharged from Ginna in recent years and the hypothetical possible dose are shown in table 20.

Environmental monitoring

Results of gross beta analyses on air particulates and water samples from the vicinity of the R. E. Ginna Nuclear Power Plant are presented in table 21. No overt evidence of effects from operation of the plant are observable from these data.

Various environmental samples, including fish, aquatic vegetation, mud, and grapes have been studied for accumulation of radioactive materials from the Ginna Nuclear Plant (*7–9*). Results of some of these analyses for fish and algae are contained in table 22. With the possible exception of some increase in the small quantities of manganese-54 observed in algae, and the reported observance by the utility of small quantities of cesium-134 in *Cladophora* from the discharge area (*18*), no effects of plant operation are observable.

Analyses of milk samples from the Ginna area have likewise been negative. Only the naturally occurring potassium-40 has been observed in milk.

External pressurized ionization chamber readings taken at the Ginna site boundary by the State DEC gave the following average hourly exposure rates (*7–9*):

1970: 7.3 μR/h
1971: 7.7 μR/h
1972: 7.1 μR/h

Appendix I to 10 CFR Part 50

On December 3, 1970 the Atomic Energy Commission published in the Federal Register (35 F.R. 18385) amendments to 10 CFR Part 50 that specified design and operating requirements for nuclear power reactors to keep levels

Table 21. R. E. Ginna Nuclear Power Plant gross beta radioactivity levels in air particulates and water

Station	Air concentration (pCi/m³) 1970	1971	1972
Ontario: Maximum	.048	0.68	0.18
Minimum	.04	.04	ND
Average	.18	.22	.07

Station	Water concentrations (pCi/liter)								
	1970			1971			1972		
	Gamma	Beta	Tritium	Gamma	Beta	Tritium	Gamma	Beta	Tritium
Ontario: Maximum	—	5	—	(a)	6	1 040	—	8	940
Minimum	—	3	—	(a)	2	ND	—	ND	ND
Average	—	4	—	(a)	4	ND	—	4	ND

[a] No discernible photopeaks.
ND, nondetectable.

Table 22. Radioactivity in biota in Lake Ontario near R. E. Ginna Nuclear Power Plant

Station	Year	Number of samples		Average concentration (pCi/kg wet weight)				
				^{137}Cs	^{134}Cs	^{60}Co	^{89}Sr [a]	^{90}Sr [a]
Fish samples								
Brookwood	1970	12	Maximum	284	ND	ND	152	3516
			Minimum	55	ND	ND	—	89
Brookwood	1971	9	Maximum	528	12	ND	29	507
			Minimum	106	ND	ND	ND	365
1000 feet offshore	1971	7	Maximum	345	ND	ND	—	996
			Minimum	169	ND	ND	—	161
Brookwood	1972	15	Maximum	737	ND	ND	ND	3900
			Minimum	ND	ND	ND	ND	1900 (2 samples)

Station	Year	Number of samples	Average concentrations (pCi/kg wet weight)						
			^{131}I	^{137}Cs	^{60}Co	^{106}Ru	^{95}Zr-Nb	^{90}Sr	^{54}Mn
Algae samples									
Water filtration plant	1970	2	681	240	ND	309	1834	279	ND
	1971	1	—	269	19	685	958	—	85
	1972	—	—	—	—	—	—	—	—
On the lake	1970	2	—	307	15	840	1719	71	20
	1971	1	—	66	ND	667	994	—	91
	1972	—	—	—	—	—	—	—	—

[a] Strontium-89 and strontium-90 values are bone concentrations.
ND, nondetectable, below minimum detectable activity.

of radioactivity in effluents to unrestricted areas as low as practicable. No numerical criteria or guidance were provided. Now, as specified in its notice of proposed rulemaking published in the Federal Register of June 9, 1971 (Vol. 36, No. III) the AEC has under consideration further amendments to 10 CFR 50 in the form of a new Appendix I. This amendment would provide numerical guides for meeting the "as low as practicable" criteria.

Briefly summarized, the proposed Appendix I provides the following:

1. For liquid releases except tritium; a limit of 5 Ci/yr per reactor and an annual average concentration not to exceed 20 pCi/liter prior to entering a natural body of water.
2. For tritium; an annual average concentration not to exceed 5000 pCi/liter prior to entering a natural body of water.
3. For gaseous releases, a dose from all reactors at a site not to exceed 10 mrem/yr at any point on the site boundary or any offsite location.

The above mentioned release limits may be exceeded provided that:

1. Maximum exposure to the whole body or any organ except the thyroid of any offsite individual due to all liquid radioactive effluent releases from a site does not exceed 5 mrem/yr.
2. Maximum exposure to the whole body or any organ except the thyroid of any offsite individual due to all gaseous radioactive effluent releases from a site does not exceed 5 mrem/yr.
3. Maximum thyroid exposure is limited to 15 mrem/yr.

This regulation is to be directed solely at light-water reactors used in the production of electric power. The AEC retains the right to set lower release limits on a case-by-case basis if it desires and if operation within the regulations already described may result in the dose to the whole body or any organ except the thyroid of any offsite individual, from all sources on a site, in excess of 5 mrem/yr, or 15 mrem/yr for the thyroid.

As has been indicated, this amendment is still under consideration at the time of preparation of this report. Facilities operating prior to its adoption will be required to meet the criteria discussed above by developing, within 36

18

months of the effective date of the regulations, technical specifications which will assure compliance.

All operating and proposed nuclear-electric generating facilities in New York, in anticipation of adoption of Appendix I, have begun or continued programs which are expected to comply with Appendix I. In some cases, this has necessitated design changes or addition of waste treatment capability. Compliance would therefore be expected from operating facilities well before the passing of 36 months. Those release quantities indicated in tables 6, 7, 13, 15, 19, and 20 under "projected future" are those anticipated to comply with this new limitation.

Nuclear Fuel Services, Inc.

Nuclear Fuel Services, a subsidiary of Getty Oil Company, started operations in 1966 as a spent fuel reprocessing plant in the town of Ashford, Cattaraugus County. The site is located about 30 miles south of Buffalo. Original design capacity was 300 tons of nuclear fuels per year or about one ton per day. The plant is equipped with an ion exchange system and a lagoon system for maintaining control of low-level liquid waste discharges. Gaseous radioactive wastes are discharged through a 200-foot stack.

The land within 25 miles of the plant is used primarily for agricultural purposes. The greatest population densities are toward Buffalo, northwest of the site. The approximate population within 10 miles of the site is 15 700.

Liquid waste

Liquid waste is discharged at a controlled rate into Frank's Creek, which flows into Buttermilk Creek and then to Cattaraugus Creek before leaving the site. Cattaraugus Creek flows to Lake Erie. There are no public drinking water supplies on any of the creeks, but Lake Erie is used as a public water supply for several municipalities, including Buffalo.

The effluent discharge rate of the plant is normally about 200 000 gallons per day. The treatment system originally consisted solely of a lagoon network for treatment of low-level liquid wastes. In May 1971, additional treatment capability in the form of a precipitation and ion exchange plant was added to the system. It is the intent of this plant to reduce concentrations of all radionuclides, except tritium, to below MPC_w (from Atomic Energy Commission's 10 CFR 20 regulation) at the point of discharge from the final holding lagoon (*20*). The lagoon network consists of two 22 000 gallon interceptors, one 300 000 gallon lagoon and two 2.3 million gallon lagoons. These lagoons provide hold-up capability of up to about 100 days, with the average being about 1 month. Prior to installation of the additional treatment facilities, NFS operated under a provisional license which limited discharges such that gross beta radioactivity in the local offsite waters (Cattaraugus Creek) was less than 150 pCi/liter.

High level liquid wastes (ca 400 gallons/tonne U) are stored onsite in vented underground steel vaults which are monitored for leakage.

NFS ceased operations in December 1971 and

Table 23. Radioactive liquid releases from Nuclear Fuel Services Reprocessing Plant [a]

Year	Radioactivity concentrations (curies)										
	Gross beta	Gross alpha	^{3}H	^{90}Sr	^{89}Sr	^{129}I	^{137}Cs	^{134}Cs	^{106}Ru	^{238}Pu	^{239}Pu
1967	31.0	0.056	4204	9.86	[b] NA	0.07	NA	NA	NA	NA	NA
1968	46.4	.139	2646	5.03	NA	.028	NA	NA	NA	NA	NA
1969	136.2	.018	5975	10.07	NA	.2	NA	NA	NA	NA	NA
1970	87.0	.105	4516	14.2	NA	.341	NA	NA	NA	NA	NA
1971	77.1	.046	3854	6.63	2.27	.211	10.02	1.83	48.2	4.2×10^{-3}	4.8×10^{-3}
1972	42.74	.026	600	.68	.077	.055	1.1	.185	6.11	7.0×10^{-4}	5.3×10^{-4}

[a] Release data from Quarterly Reports, reference *20*.
[b] NA, not available.

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has not processed fuel since that time. Cleanup and decontamination in preparation for construction of additional throughput capacity have been carried out. The resumption of operations at the old capacity or at some expanded capacity is not expected until about 1979. A record of historical releases of liquid wastes is presented in table 23.

Gaseous waste discharge

Gaseous wastes are discharged to the environment via a 200-foot stack. Because of the long decay times prior to dissolution (150 day minimum—usually significantly longer) the only radioactive noble gas of significance is krypton-85. Some small amounts of iodines and particulates are also present, as is tritium. Krypton-85, tritium, and iodine-129 released in gaseous effluents have all been subject to various studies around NFS (*21–23*). Iodine-129 in particular has come under careful scrutiny recently by the State Department of Environmental Conservation (*24*). The amounts of gaseous radioactive effluents released from NFS in recent years is presented in table 24 (*20*).

Environmental monitoring

The NFS facility, because it is the first privately owned commercial fuel reprocessing plant in the United States, has been the object of some of the most extensive scientific evaluations carried out in the environmental radiation field. Preoperational environmental analyses began at the site in 1964 and routine post-operational monitoring has been carried out by several agencies since reprocessing commenced. In addition, many specialized specific studies have been conducted by various interested groups and organizations. The graphs in figures 4 through 10 show the changes observed since 1967 in various environmental radiation parameters. These data are reported by NFS as the results of its own monitoring programs (*25*). The graphs are self-explanatory but a few particular observations might be mentioned here.

First, the onsite gross beta activity in air is usually fractionally higher than the offsite average. A generally decreasing trend is observed, particularly since mid-1971, in both alpha and beta concentrations in air.

Levels for gross beta, strontium-90 and tritium in Cattaraugus Creek are observed to have increased significantly above preoperational background levels in the late 1960's, then decreased somewhat since 1970 levels.

Gross beta and alpha activity in silt taken from Cattaraugus or Buttermilk Creeks both show increases from 1967 levels with decreases following mid-1971. Concentrations of gamma-emitting nuclides, particularly cesium-137 and ruthenium-106, are of sufficient concentrations on creek bottoms and banks in the immediate

Table 24. Radioactive gaseous releases from Nuclear Fuel Services Reprocessing Plant

Year	Radioactivity concentration (curies)						Total fuel processed (tons)
	^{85}Kr	^{3}H	^{131}I	^{90}Sr	^{89}Sr	^{106}Ru	
1967	327 000	[a] 500	<0.06	[b] 0.483			136.5
1968	110 000	500	6.6×10^{-3}	[b] 1.07			139.0
1969	[c] 360 000	500	<.03	[b] .119			120.3
1970	[c] 625 000	500	<.03	[b] .187			NA
1971	220 800	1 070	2.4×10^{-3}	3.57×10^{-4}	2.73×10^{-4}	1.32×10^{-3}	68.8
1972	No dissolutions	5.47	$.96 \times 10^{-3}$	4.12×10^{-3}	2.1×10^{-3}	2.94×10^{-3}	None

[a] 1967 to 1970 tritium releases as estimated, reference *23*.
[b] Gross beta on total particulates.
[c] Estimated using one half the reported monthly maximum percent release limits for entire month's operation.
NA, not available.
Release limits: particulates—0.1 μCi/s
iodine—3.3 Ci/yr
krypton-85—12 600 Ci/day.

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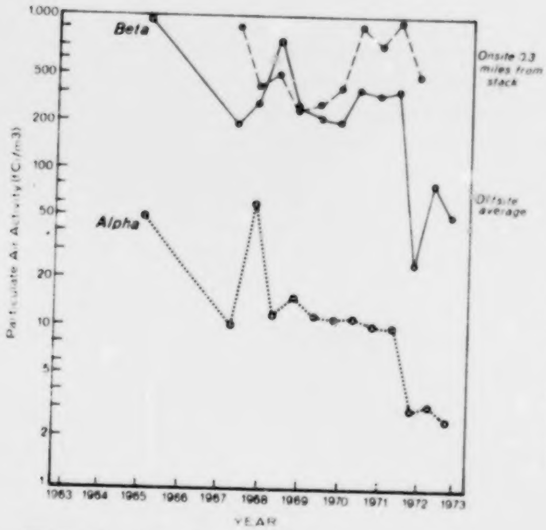

Figure 4. Air activity at site perimeter stations

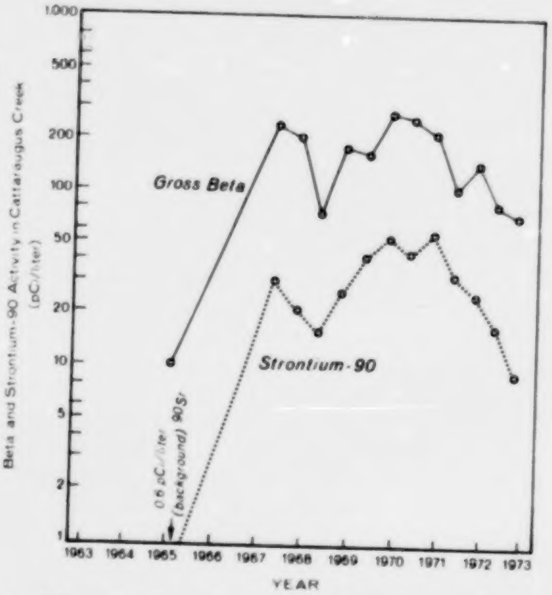

Figure 6. Gross beta and strontium-90 activity in Cattaraugus Creek, downstream

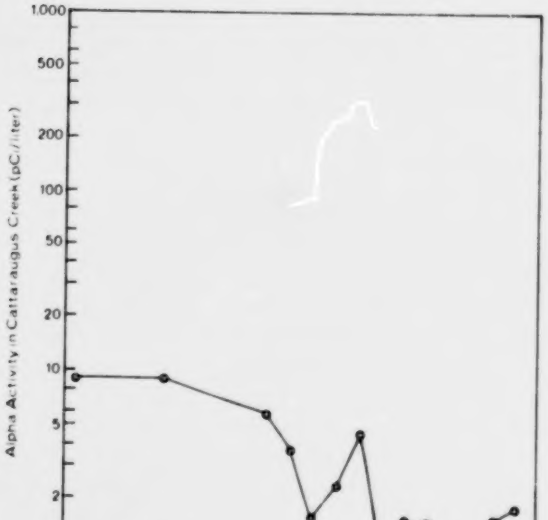

Figure 5. Alpha radioactivity in Cattaraugus Creek, downstream

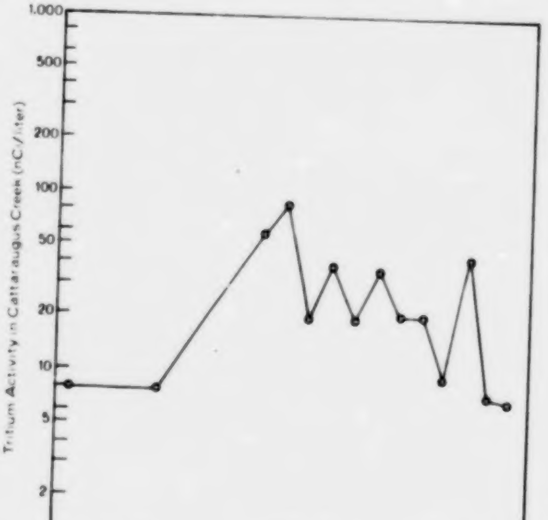

Figure 7. Tritium activity in Cattaraugus Creek, downstream

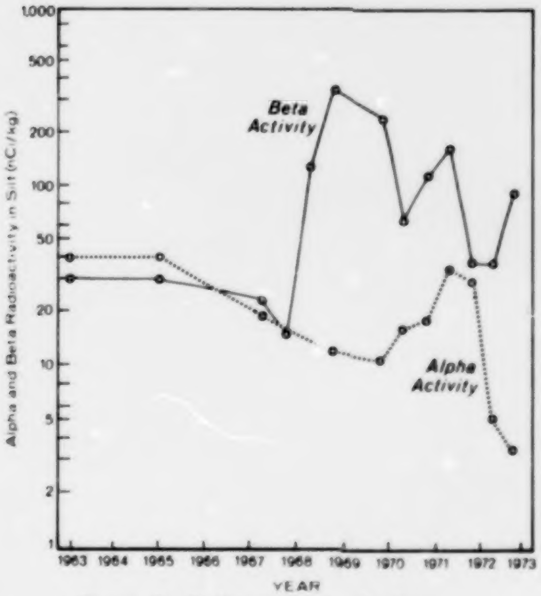

Figure 8. Radioactivity in silt from Cattaraugus Creek

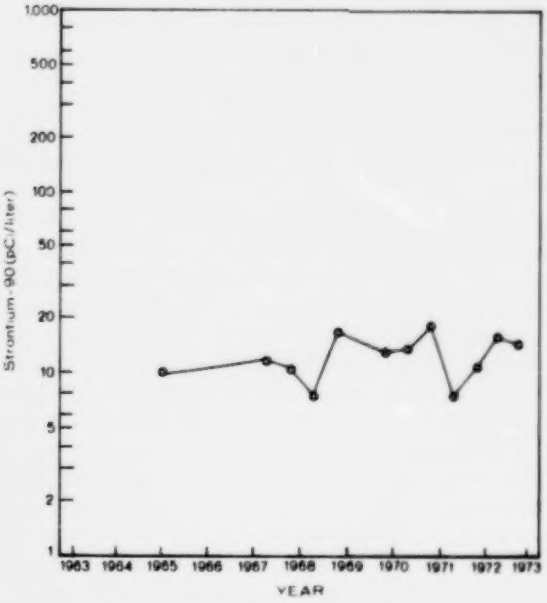

Figure 9. Strontium-90 in milk from NFS farm

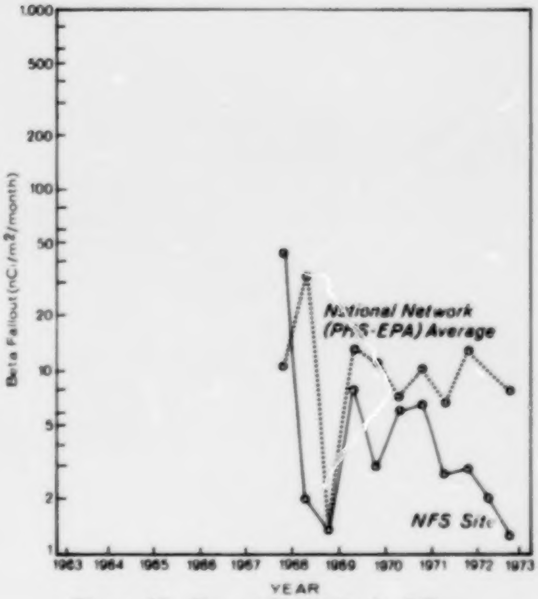

Figure 10. Beta radioactivity in fallout

vicinity of the site to effect changes in dose readings above the creek when water flow is down. Such concentrations are variable subject to pH of the water, reproducibility in sampling, and scouring by high water flow.

The milk from the NFS farm showed relatively stable concentrations of strontium-90 at a level less than 10 percent of allowable FRC limits for populations. This level is comparable to the level of strontium-90 in other milk samples in the EPA network. No iodine-131 above the minimum detectable activity of 10 pCi/liter has been detected.

The fallout sampling station on the site has reported levels somewhat paralleling and consistently lower than the Environmental Protection Agency national network average.

Two biological species which have elicited interest at NFS are deer and fish (*26*). Both have been suggested as the possible pathway of concern for the "maximum" individual. Concentrations of radionuclides in fish and deer from the NFS area are given in tables 25 and 26. Both averages and maximum observed concentrations are given for fish whereas only maximum observed concentrations are listed for deer.

Table 25. Concentrations of radionuclides in fish from NFS vicinity

Date		Concentration (pCi/kg wet weight)				
		^{90}Sr (flesh)	^{90}Sr (bone)	^{134}Cs (flesh)	^{137}Cs (flesh)	^{3}H [b] (flesh)
Fish samples:						
1970	Average [a]	3 630	15 400	—	—	21 000
	Maximum [a]	14 500	620 000	5 890	34 800	—
January-June 1971	Average	280	6 300	2 100	6 900	9 500
	Maximum	280	18 500	2 100	6 900	—
July-December 1971	Average	660	—	10	71	46 000
	Maximum	660	290 000	301	1 670	—
January-June 1972	Average	80	740	700	1 500	7 700
	Maximum	6 900	25 000	1 264	6 104	—
July-December 1972	Average	260	1 340	540	2 300	7 200
	Maximum	1 710	—	—	—	—

[a] Average reported by NFS, maximum from NFS or DEC data on rough fish obtained onsite.
[b] Equilibrium with water concentration is assumed.

Table 26. Concentrations of radionuclides in deer from NFS vicinity

Date	Concentration (pCi/kg wet weight)								
	^{137}Cs	^{134}Cs	^{60}Co	^{106}Ru	^{89}Sr	^{90}Sr	^{65}Zn	^{239}Pu	^{129}I in thyroid (pCi/g)
Deer samples [a]									
1970	4 687	784	56	ND	7	28	107	—	3 700
1971	1 428	314	—	108	—	10	232	0.72	1 400
1972	356	65	ND	ND	ND	30	142	1.90	360

[a] All values are maximums reported by DEC in muscle tissue; iodine-129 in thyroids.
ND, nondetectable.

Comparisons between data on fish concentrations at NFS and those at other facilities readily illustrate that much larger concentrations of nuclides are occurring near the NFS site. This is due both to the slightly larger releases which were taking place at NFS and to the much smaller dilution flows available. Consumption of 4.3 kg annually of fish containing radionuclide concentrations reported in 1971 would result in 1.3 mrem/yr whole body dose from radioactive cesiums and 1.2 mrem/yr bone dose from strontium-90 (*16*).

Background deer samples taken near Albany by the State DEC in 1970 showed no observable radionuclides in four specimens, except for cesium-137, which may be associated with fallout (*7*). Maximum observed concentration of cesium-137 was 140 pCi/kg, which is significantly less than the 4687 pCi/kg observed in one NFS sample. Recalling that fallout at NFS is consistently below the national average points to the conclusion that the NFS facility is the source of this radionuclide in this case. Consumption of 4.8 kg annually of deer meat containing the average concentrations reported in 1971 has been calculated to correspond to a 0.4 mrem/yr whole-body dose from radioactive cesiums (*16*). Other investigations have identified individuals consuming up to 50 kg/yr. For both fish and deer consumption pathways, the population at risk is small and confined primarily to the near vicinity of Cattaraugus Creek.

Because of the system of milk pooling which exists in New York State area, milk contamination by radioiodines might affect a much larger population. For this reason, the appearance of increased levels of iodine-129 in deer thyroids in 1970 led to studies by EPA and the State DEC which concentrated on this nuclide (*22–24*). Though only limited data are available, it is estimated that about 0.9 curies of iodine-129 were released from NFS in liquid effluents from April 1966 to July 1971. This is about 20 percent of the estimated 4.4 curies present in all the fuel processed during this time. It is estimated that a minimum of 1.1 curies or 25 percent of the iodine-129 in the fuel was released in gaseous effluents. During this period, the removal system consisted only of a chemical scrubber. For future operations, NFS will install a caustic scrubber and a highly efficient silver zeolite absorber. The studies indicate that such improved iodine removal systems are warranted, since iodine-129 levels in animal species and in the environment reached 10^3 or 10^4 times background levels. Also, iodine-129 was identified in milk samples (up to 2.1 pCi/liter) in the period of November 1971 through May 1972, when animals were on stored feed harvested in the summer of 1971. No long-term buildup in milk has been identified as yet. The half life by weathering is probably in the range of that of iodine-131, which is 12 to 20 days, and secretion into the milk once the iodine is ingested by the cow occurs in less than 1 day. Root uptake or resuspension and adsorption have not visibly contributed to iodine-129 reaching the food chain.

Pressurized ionization chamber readings by the State DEC gave the following average hourly exposure rates (*7–9*):

1970: 9.3 μR/h
1971: 8.6 μR/h
1972: 8.4 μR/h

Brookhaven National Laboratory

Brookhaven is located on a 5265 acre site in the center of Long Island, about 60 miles east of New York City. Three types of operations contribute to the local background. These are:

a. Gaseous and particulate radioactivity contained in cooling air effluent from the two reactors and from the hot lab,
b. Low-level liquid waste releases to the environment, and
c. Radiation from two multicurie field gamma sources.

Of these, a and b, result in small quantities of radioactive materials reaching the offsite environment.

The quantities of radioactive materials released in liquid and gaseous effluents from various activities at the laboratory in recent years are indicated in tables 27 and 28, respectively (*27*).

The following acronyms are applicable for Brookhaven:

BGRR—Brookhaven Graphite Research Reactor
HFBR—High Flux Beam Reactor
MRR —Medical Research Reactor
MRC —Medical Research Center

Environmental monitoring

Brookhaven National Laboratory has monitored various environmental media for several years (*28*). Recently, the State DEC has also done environmental monitoring. The DEC has annually analyzed milk and river water samples from the vicinity since 1970. In addition, special samples such as ducks (in 1970), clams (1970) and harbor seal (1971) have been analyzed. Small amounts of radio-nuclides

Table 27. Radioactive materials discharged in liquids from Brookhaven National Laboratory [a]

Year	^{3}H (Ci)	Quantity (mCi)								
		Gross beta	^{7}Be	^{60}Co	^{65}Zn	^{90}Sr	^{95}Zr-Nb	^{131}I	^{137}Cs	^{144}Ce
1967	12.4	54.9								
1968	20.5	22.0								
1969	18.2	20.8								
1970	35.6	29.1								
1971	11.8	31.9								
1972	6.32	35.6	2.53	0.27	0.42	5.11	0.51	5.91	11.02	6.79

[a] All contaminated flow passes through sand filter beds where approximately 15 percent passes into the ground water and 85 percent to the Peconic River. During 1972 of the Peconic River flow 45 percent went to ground water before leaving the laboratory perimeter and 55 percent went downstream. Thus, on the average, only 47 percent of the effluent flow ends up downstream. This same fraction of tritium would have ended up downstream but because of varying chemical differences, carryover fractions differ slightly for other nuclides. Since these fractions are influenced by stream flow rates, the amounts indicated are the total of the input to the Peconic River and that passing to ground water onsite.

Table 28. Radioactive gaseous discharges Brookhaven National Laboratory

Source	Gaseous tritium [a] releases (Ci)			
	1969	1970	1971	1972
BGRR [b]	(376 total)	—	—	—
HFBR		681	434	602
MRR	—	—	—	—
MRC	—	—	0.16	9.12
Chemistry	—	—	12.3	18.3
Van de Graaff	—	—	95.2	276.8
Total	376	681	541.7	906.2
	Argon-41 release (Ci)			
BGRR	193 000	—	—	—
MRR	1 480	1 347	556	605

[a] All as tritiated water vapor except 7.14 Ci in 1971 and 216.0 Ci in 1972 as gas from the Van de Graaff.

[b] In addition, 12.0 mCi of gross beta particulates and 6.8 mCi of iodine-131 were discharged in 1969 while the BGRR was still in operation.

characteristic of weapons test fallout were sometimes detected, but no isotopes attributable to operations of Brookhaven have been found (*7–9*).

Table 29 gives tritium amounts and concentrations in the Peconic River at the boundary of Brookhaven over the past few years. Large fluctuations are apparently due to variations in activities at the laboratory. The principal source of tritium is operation of the waste evaporator, which currently produces about 150 mCi per operating day in about 1500 gallons of condensate. This has increased over the years roughly proportionately to the DTO concentration in primary coolant of the High Flux Beam Reactor. Production of tritium from this source was about 50 mCi per operating day in early 1969 compared to 150 mCi in 1972.[3]

Table 30 provides data for the same years (1969–1972) for radionuclide concentrations in precipitation and in milk from the dairy nearest BNL. As indicated, the State Department of Environmental Conservation began analyzing milk samples from this dairy in the second quarter of 1970. Besides strontium-90, the DEC analyzes for iodine-131, cesium-137, strontium-89, and tritium. The reported results for cesium-137 are about the same as those given by analyses at BNL. Iodine-131, strontium-89, and tritium concentrations have, on the average, been below detectable limits.

The precipitation data demonstrate the seasonal pattern of transfer of fallout materials from the stratosphere, generally being at a maximum in late spring or early summer.

The concentration of strontium-90 in milk from the nearest dairy was among the highest reported anywhere in New York State in 1972, averaging 16 pCi/liter. Such diverse locations as Cattaraugus County, Erie County, and Oswego County gave results of 15, 15, and 13 pCi/liter, respectively, so that the concentrations at this location were not anomalously

Table 29. Tritium amounts and concentrations at BNL perimeter, Peconic River samples, 1969 to 1972

Date	1969		1970		1971		1972	
	Amount (Ci)	Concentration (nCi/liter	Amount (Ci)	Concentration (nCi/liter)	Amount (Ci)	Concentration (nCi/liter)	Amount (Ci)	Concentration (nCi/liter)
January	0.1	2	0.3	3	0.7	[a] 11	0.01	2
February	.1	2	1.1	[a] 12	.3	[a] 5	.01	1
March	.3	5	6.4	[a] 75	.4	[a] 4	.03	1
April	.1	2	1.6	[a] 10	.4	[a] 5	.1	[a] 2
May	.7	10	3.5	[a] 22	.5	[a] 7	.08	1
June	.3	[a] 4	3.7	[a] 30	.7	[a] 28	.07	1
July	.4	[a] 16	2.0	[a] 19	.04	[a] 6	.2	1
August	.6	[a] 7	1.5	[a] 14	.02	[a] 4	.03	1
September	.1	2	.4	[a] 18	.02	[a] 3	.03	[a] 2
October	1.4	[a] 34	.6	[a] 18	.02	[a] 3	.3	[a] 13
November	.8	[a] 14	.2	[a] 4	.01	2	.4	[a] 7
December	.5	[a] 6	.3	[a] 7	.01	1	1.1	[a] 7
Total	5.4		21.6		3.1		2.4	
Average		9		19		8		3

[a] Months during which evaporator was operated.

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[3] Memorandum from A. P. Hull to C. B. Meinhold re: tritium concentrations in the Peconic River, Brookhaven National Laboratory.

Table 30. Comparison of fallout-related levels in precipitation and milk in BNL area, 1969 to 1972

Month	1969				1970				1971				1972			
	Precipitation (nCi/m²)		Milk from nearest dairy (pCi/liter)		Precipitation (nCi/m²)		Milk from nearest dairy (pCi/liter)		Precipitation (nCi/m²)		Milk from nearest dairy (pCi/liter)		Precipitation (nCi/m²)		Milk from nearest dairy (pCi/liter)	
	Gross beta	^{90}Sr	^{137}Cs	^{90}Sr	Gross beta	^{90}Sr	^{137}Cs	^{90}Sr	Gross beta	^{90}Sr	^{137}Cs	^{90}Sr	Gross beta	^{90}Sr	^{137}Cs	^{90}Sr
Jan	0.98	0.02	19		1.0	0.03			1.57	0.04	18		2.39	0.05	12	
Feb	1.97	.06	—		2.3	.05		—	2.34	.12	24	10	1.90	.07	16	13
Mar	7.27	.15	—		5.8	.21			4.95	.17	14		2.56	.11		
Apr	9.26	.15	10	—	5.5	.18	18		4.59	.05	10		15.87	.11	15	
May	10.74	.06	19	—	9.9	.21	12	10	14.03	.30	20	5	6.78	.08		7
June	8.67	.10	19	—	10.4	.18	27		4.39	.27	20		7.41	.10		
July	13.29	.12	8	—	15.4	.24	28		2.70		15		1.40	.02	17	
Aug	7.12	.12	20	—	8.7	.17	38	17	2.53	.13	22	11	.16	([a])		21
Sept	3.52	.06	10	—	1.0	.07	28		.38	.05	20		.40	.11		
Oct	11.30	.04	5	—	1.5	.05	27		1.25	.14	22		.85	.03	14	
Nov	2.90	.06	10	—	4.2	.11	20	13	4.75	.11	14	10	.82	([a])		NA
Dec	5.04	.14	—	—	2.0	.06	33		4.77	.05	11		.95	([a])		
			—	—			—				—					
	83.16	1.12		—	67.7	1.56			46.67	1.43			44.49	0.81		
			[b] 13	—			[b] 26 [c] 28	[c] 14			[b] 18 [c] 28	[c] 9			[b] 16 [c] 17	[c] 16

[a] Information not available.
[b] Measurements by Brookhaven National Laboratory.
[c] Measurement by Department of Environmental Conservation.
NA, no analysis.

large and not conclusively contributable to any operations at BNL.

External PIC readings were taken around BNL in 1970. The average reported dose rate of 7.3 μR/h was the lowest in the State along with the same value reported around the Ginna reactor (7).

Conclusion

As a means of making some evaluation of the cumulative impact of all the facilities, the total yearly discharges for all of those discussed here have been compiled in table 31. Then, by taking population exposures (man-rem within 50

Table 31. Total radioactive effluent discharges from major nuclear facilities in New York State

Facility	Liquid releases (Ci)				Noble gas releases (Ci)			
	1969	1970	1971	1972	1969	1970	1971	1972
Indian Point Station Unit 1	28	7.8	81	25.4	600	1 800	380	543
Nine Mile Point Nuclear Station Unit 1	.9	28	32.2	34.5	60	9 500	253 000	520 000
R. E. Ginna Nuclear Power Plant	.02	10	.96	.38	<1	10 000	31 800	11 800
Nuclear Fuels Service	136.2	87	77.1	42.8	360 000	625 000	220 800	—
Brookhaven	.01	.02	.01	.04	194 480	1 347	556	605
Total	165	133	191	103	555 140	647 647	506 536	532 948

Facility	Tritium in liquids (Ci)				Airborne halogens and particulates [a] (Ci)			
	1969	1970	1971	1972	1969	1970	1971	1972
Indian Point Station Unit 1	1 000	410	725	574	0.025	0.075	0.21	0.93
Nine Mile Point Nuclear Station Unit 1	<1	20	12.4	28	<.001	<.06	.78	.95
R. E. Ginna Nuclear Power Plant	<1	110	154	119	.001	.05	.17	.035
Nuclear Fuels Sevices	5 975	4 516	3 854	600	.12	.19	.007	.074
Brookhaven	5.4	21.6	3.1	5.9	.021	([b])	([b])	([b])
Total	7 082	5 078	4 749	1 327	0.168	0.375	1.17	1.99

[a] Excludes 1.1 Ci iodine-129 released from NFS in 1966 through 1972.
[b] Insignificant.

Table 32. Population exposures within 50 miles of nuclear facilities in New York State [a]

Location	Dose from liquid releases (man-rem)			
	1969	1970	1971	1972
Indian Point Station Unit 1	2.3	0.6	6.5	2.0
Nine Mile Point Nuclear Station Unit 1	.41	12.8	14.7	15.7
R. E. Ginna Nuclear Power Plant	2.4×10^{-3}	1.2	.12	.05
Nuclear Fuels Services	37.7	27.2	23.5	6.0
Brookhaven	.015	.03	.015	.06
Totals	40.4	41.8	44.8	23.7
	Dose from gaseous releases (man-rem)			
Indian Point Station Unit 1	1.7	5.0	1.1	1.6
Nine Mile Point Nuclear Station Unit 1	1.5×10^{-3}	.24	6.3	13.0
R. E. Ginna Nuclear Power Plant	3.4×10^{-4}	3.4	10.5	4.0
Nuclear Fuels Services	1.6	2.8	1.0	.0
Brookhaven [b]	.03	.05	.04	.05
Total	3.3	11.5	18.9	18.6

Year	Dose (man-rem)		
	Liquid	Gaseous	Total
1969	40.4	3.3	43.7
1970	41.8	11.5	53.3
1971	44.8	18.9	63.7
1972	23.7	18.6	42.3
Total	150.7	52.3	203.0

[a] The doses include all pathways for the given media.

[b] Primarily from airborne tritium (906 curies in 1972).

miles) reported in the literature or an environmental impact statement for the facilities, and by ratioing the reported release quantities in these reports to those given in this report for the various years, table 32 was compiled. This table gives the man-rem exposure total by gaseous or liquid release within 50 miles of each facility (*11,17,19,26,28,29*).

Because of possible changes in nuclide constituency with release quantities, direct ratioing in this manner is not strictly legitimate. Errors encountered in this usage would not be expected to exceed an order of magnitude. It is therefore possible to conclude that the population dose to citizens of New York during the period examined by this study was less than 500 man-rem per year and, due to the conservatism of the assumptions, probably less than 50 man-rem. For comparisons, it may be noted that a population of 20 million persons might be expected to incur on the order of 4 million man-rem per year from other sources, natural and medical, if we assume these other sources to average 200 mrem per person per year. As a further comparison, the total man-rem exposure at a single facility (Nine Mile Point Nuclear Station Unit 1) incurred by employees and visitors has ranged from 1.82 in 1969 to 285.5 in 1972 (*30*).

Acknowledgment

Personal thanks are expressed to Mr. C. Weaver and C. Robbins, FOD, EPA for providing initial data and draft reports and Mr. Weems Clevenger, Director, Environmental Programs Division, EPA Region II for guidance and direction in the early stages of this report.

Special thanks are extended to Ms. Sonia Aronson for her diligent efforts in preparing the original manuscript.

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Appendix 1[a]

Minimum detectable sensitivity

Air (pCi/m^3)

Gross beta	0.003

Fallout (pCi/ft^2/day)

Ruthenium-106	25
Zirconium-niobium-95	5
Strontium-89	1
Strontium-90	0.25
Hydrogen-3 (pCi/liter)	500

Water and milk (pCi/liter)

Gross Alpha	1
Gross Beta	1
Cesium-137	10
Cesium-134	10
Cobalt-60	15
Ruthenium-106	50
Zinc-65	20
Antimony-125	20
Zirconium-niobium-95	10
Barium-140	15
Iodine-131 (isotopic scan)	10
Iodine-131 (ion exchange)	3
Plutonium-238	0.02
Plutonium-239, -240	0.02
Strontium-89	5
Strontium-90	1
Iodine-129	0.3
Hydrogen-3	500

Maximum permissible concentration

The maximum allowable U.S. AEC yearly average concentration in air for discharges to unrestricted areas in pCi/m^3 are:

Gross beta; varies with isotopes present

Strontium-90	30
Plutonium-238	0.07
Plutonium-239	0.06
Plutonium-240	0.06
Cesium-134	1,000
Cesium-137	2,000
Ruthenium-106	3,000
Zirconium-95	4,000
Barium-140	4,000
Krypton-85	300,000

The maximum allowable U.S. AEC yearly average concentration in water for discharges to unrestricted areas in pCi/liter are:

Gross beta; varies with isotopes present
Gross alpha; varies with isotopes present

Iodine-129	60
Iodine-131	300
Strontium-90	300
Strontium-89	3,000
Uranium-234	3,000
Uranium-235	3,000
Uranium-238	4,000
Plutonium-238	5,000
Hydrogen-3	3,000,000
Plutonium-239	5,000
Plutonium-240	5,000
Cesium-134	9,000
Cesium-137	20,000
Cerium-144	10,000
Cobalt-60	30,000
Ruthenium-106	10,000
Antimony-125	100,000
Zinc-65	100,000
Zirconium-95	60,000
Niobium-95	100,000

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[a] This table is taken from the 1972 "Annual Report of Environmental Radiation in New York State," New York State Department of Environmental Conservation, Albany, N.Y. 12201.

Calculated Field Intensities Near a High Power UHF Broadcast Installation

Richard A. Tell and John C. Nelson[1]

A UHF transmitter site in the Washington, D.C. area, which is used cooperatively by two UHF television stations, was chosen for calculations of effective radiated power (ERP), field strength, and power density. Using the specifications for the two broadcasting stations, field strengths and power densities were calculated and presented graphically.

The calculated power densities for this broadcasting installation showed that the exposure values fall very sharply as the distance from the tower increases to about 1 mile. At distances beyond 0.5 miles, the maximum exposure values calculated were about 2.7 $\mu W/cm^2$ occurring at 0.5, 3.3, and 4.5 miles. As the height above ground at the receiving point is increased, the exposure value generally increases.

Based on the calculations for the 135 degree radial and the computed population distribution, it appears that approximately 86 000 people reside in an area within which the estimated exposure is 1 $\mu W/cm^2$ or more.

This report concerns itself with ambient radiofrequency (RF) exposure levels in the near vicinity of a high power UHF television (TV) broadcast installation in the Washington, D.C. metropolitan area. Recently, attention has been focused on the discovery of undesirable UHF interference to cardiac pacemakers (*1*) and the long standing interest in the possible long-term, low-level (nonthermal) biological effects of electromagnetic energy in this frequency range (*2*). Though the potential contribution to human RF exposure from broadcast stations has been examined in general (*3*), this report deals specifically with calculation of radiation fields of the UHF broadcast service. More exactly, a first order approximation of radiated field intensity, utilizing transmitter characteristics, antenna vertical radiation patterns, and topographic terrain information, was used to develop power density and field strength curves as a function of distance from a UHF TV installation and varying heights above ground. Additionally, the 1970 census data were used in an automated manner to compute the population residing within areas subject to specific calculated levels of RF exposure.

A UHF transmitter site in the Washington, D.C. area was chosen for the calculations which follow. This particular location (figure 1) is the site of WDCA (channel 20, commercial) and WETA (channel 26, educational), the transmitting antennas of both stations being colocated on the same tower. Table 1 summarizes some of the technical specifications for these two stations. The combined effective radiated power (ERP), including both visual and aural carriers, is approximately 5.6 MW and represents one of the most powerful UHF outlets in this country. A maximum ERP of 5.0 MW for a single station is allowed by the Federal Communications Commission (FCC). As of December 1, 1971, there were 306 UHF television stations on the air in the United States (*4*).

Table 1. Pertinent information for UHF TV complex

UHF TV complex	Channel	
	WDCA-20	WETA-26
Visual carrier frequency (MHz)	507.25	543.25
Aural carrier frequency (MHz)	511.75	547.75
Maximum antenna gain (dB)	13.42	14.39
Antenna manufacturer	RCA	GE
Antenna type	TFU-22g	TY-106C
Visual maximum ERP (kW)	4 000	1 074
Aural maximum ERP (kW)	400	107.4
Elevation of antenna center of radiation (feet)	1 016	1 028

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[1] U.S. Environmental Protection Agency, Electromagnetic Radiation Analysis Branch, Office of Radiation Programs, 9100 Brookville Road, Silver Spring, Md. 20910.

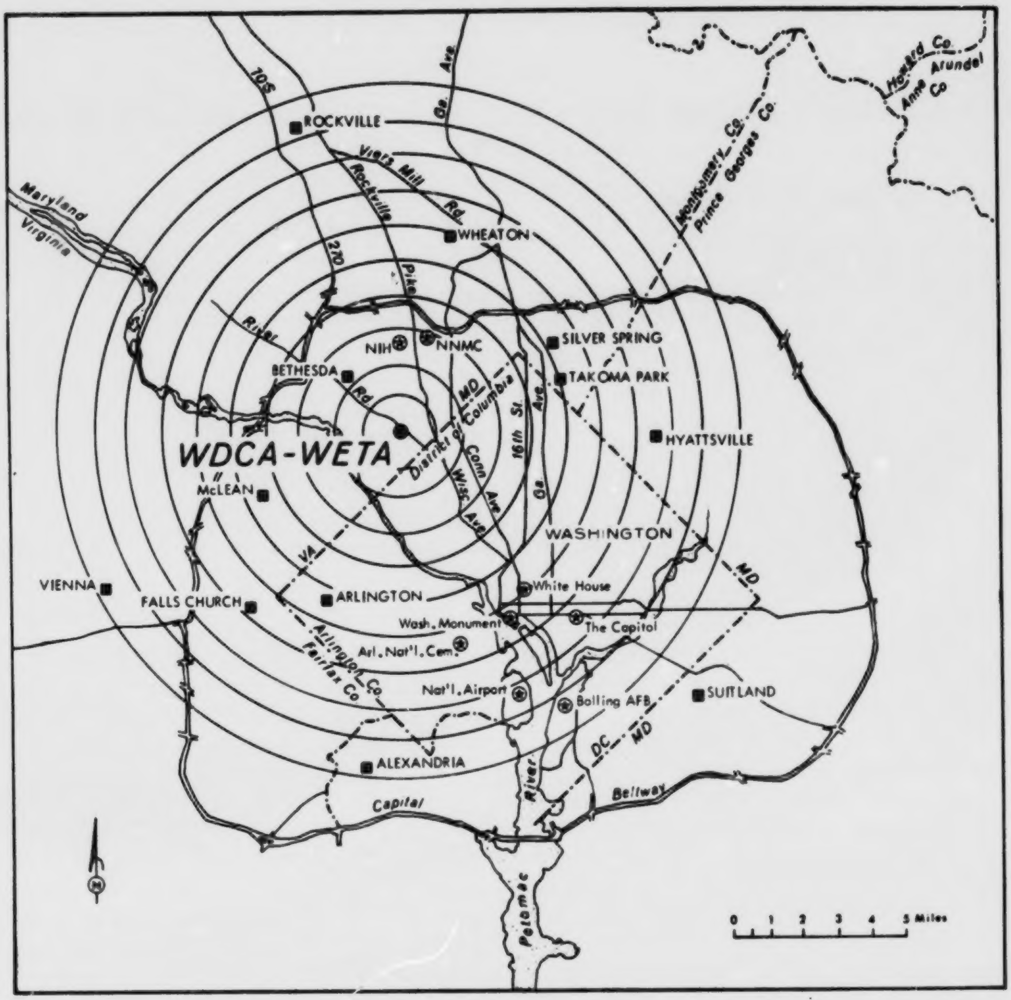

ROCKVILLE
WHEATON
SILVER SPRING
TAKOMA PARK
HYATTSVILLE
BETHESDA
NIH
NNMC
WDCA-WETA
McLEAN
VIENNA
FALLS CHURCH
ARLINGTON
WASHINGTON
White House
Wash. Monument
The Capitol
Arl. Nat'l. Cem.
Nat'l. Airport
Bolling AFB
SUITLAND
ALEXANDRIA
Capital
Beltway
Potomac
River
Maryland
Virginia
Montgomery Co.
Prince Georges Co.
Howard Co.
Anne Arundel Co.
Arlington Co.
Fairfax Co.
District of Columbia
MD
VA
DC
Rockville Pike
Viers Mill Rd.
Ga. Ave.
16th St.
Conn. Ave.
Wisc. Ave.
270
70S
0 1 2 3 4 5 Miles
N

Figure 1. Location of WDCA-WETA transmitting tower

Method

The problem of calculating ground level field intensities from elevated UHF broadcast antennas over a spherical earth can become extremely complex requiring tedious ground reflection coefficient computations (*5–7*). Even when utilizing these more sophisticated analytical techniques, variations in actual terrain and electromagnetic obstacles such as buildings, overhead power lines, automobiles, and foliage often distort the actual field values significantly from those which were calculated. For this reason, a simplified approach was used to estimate, for hazard purposes, the RF field intensities around the WDCA-WETA complex. Figure 2 diagrammatically illustrates this approach. For any exposure point, B, elevated above the earth, there exist two incident waves emitted by the transmitting antenna at a height h_1 above ground; one wave is directly radiated from the tower to the exposure point while another is reflected from the ground at point C. These two waves, depending on their relative

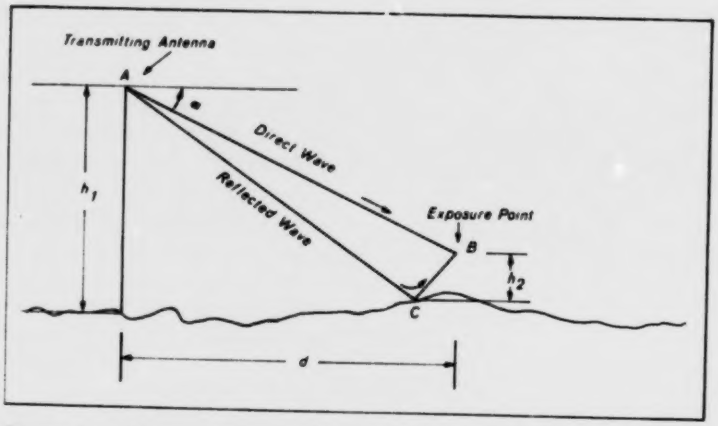


Figure 2. Diagram of approach for estimation of RF field intensities

phase and intensity, will combine (constructively or destructively) at point B to produce a resultant field. In reality, the resultant field tends to oscillate about the value given by the direct wave alone, depending on whether point B is moved vertically above ground or laterally away from the source. In the model used in this report, a worst case assumption has been made, in accordance with FCC recommendations (*8*), that the ground-reflected wave is equally intense as the direct wave and adds vectorially to double the field strength value at point B over what could be accounted for by considering only the direct wave. The assumption of 100 percent ground reflection offers a conservative means of evaluating the maximally potentially hazardous UHF fields.

The RF exposure values calculated were obtained through the free space relation:

$$E_B = \frac{2 R_\alpha \sqrt{30\, Pt}}{d}$$

where:

E_B = field strength (V/m) at point B,
R_α = relative field factor of TV antenna vertical radiation pattern,
Pt = sum of maximum visual and aural ERP for a given station (W), and
d = distance of point B from antenna tower (m).

The relative field factor, R_α, is determined from manufacturers data for each transmitting antenna as a function of the depression angle α. A plot of R_α vs. depression angle is known as the vertical radiation pattern for a TV broadcasting antenna. Figure 3 is the vertical pattern for the WDCA transmitting antenna. This pattern was obtained from station records maintained by the FCC. Normal practice in plotting relative field data limits the published curves to depression angles of approximately 10 to 11 degrees below the horizontal. Thus, for areas extremely close to the antenna installation where the depression angle may be very steep, data are usually not included in the pattern. However, beyond angles of 10 degrees or so, R_α is usually not changing, and if so, only within a few percent of its value at 10 degrees. For the calculations here, advice from the manufacturers indicated that an R_α value equal to the 10 degree value was applicable for all steeper depression angles.

In practice, actual terrain elevation values (taken from USGS quadrangle topographic maps) were used to compute α and the antenna-to-exposure point distance, each 0.1 mile from the tower. A total of eight equally spaced radials (0 to 10 miles) were used to examine possible differences in ground level values due to topographic features in different directions from the tower site.

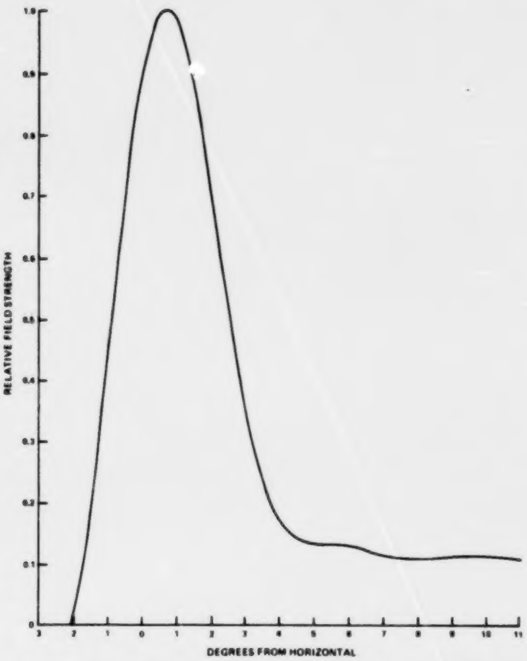


Figure 3. Vertical radiation pattern for the WDCA transmitting antenna

From the calculated field strengths for each station, the resultant power densities were determined by:

$$W = \frac{E^2}{Z_0}$$

where:

W = power density (W/m^2),
E = field strength (V/m), and
Z_0 = intrinsic impedance of free space = $120\ \pi$ ohms.

Exposure values were determined for field strength in units of V/m and dB/(μV/m) and for power density in units of $\mu W/cm^2$ and dB/($\mu W/cm^2$).

An estimate of the population residing in the vicinity of this UHF broadcast installation was made by modifying the computer programs developed by the Institute for Telecommunications Sciences (ITS) in Boulder, Colo. (*9*). The ITS technique allows computer retrieval of U.S. Census Bureau data stored by geographical coordinates and computation via a model of the population within annular rings about a given location. The program was modified to allow calculation at 0.1 mile intervals. This model when compared with manual techniques of estimating population was found to have an accuracy of better than 1 percent at a radial distance of 10 miles (*10*). The accuracy is dependent upon the total number of census enumeration districts included within the area in question; thus, as the radial distance decreases to zero, the accuracy becomes poorer. At very short distances, this error has not been evaluated. Using this approach, however, values for the population in circular areas, increasing by 0.1 mile in radius, were determined for the WDCA-WETA site up to 10 miles.

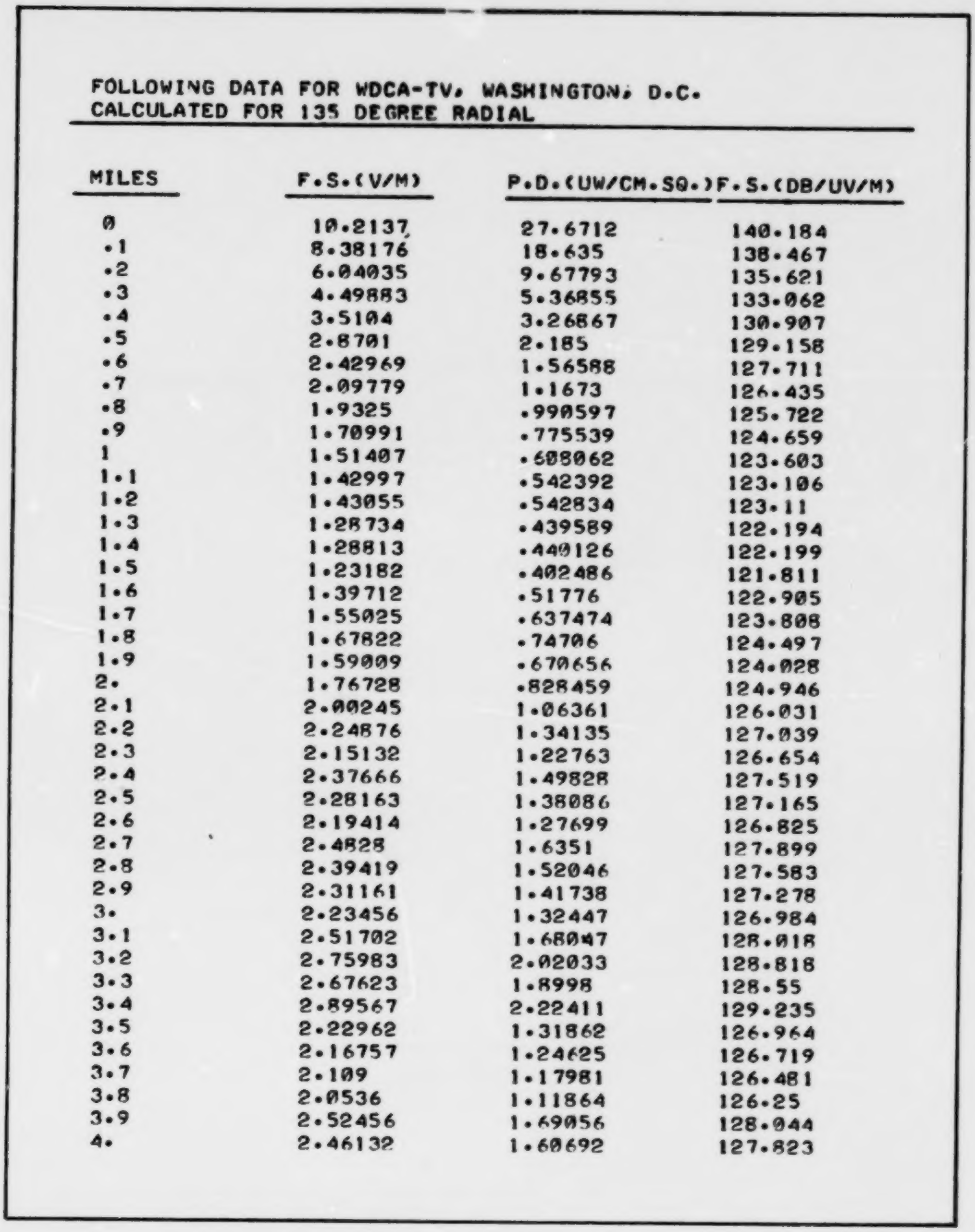
Results

Table 2 is a sample computer output for WDCA-TV showing the calculated field strength and power density for a distance up to 4 miles. In this listing, the field strength is that value which would be associated with the summation of both visual and aural carriers. The results of these and calculations along other radials are given in figure 4. This graph represents a family of eight curves showing very little effect of differences in terrain profiles. A power density of slightly more than 28 $\mu W/cm^2$ is found directly beneath the antenna at ground level while at 10 miles, the exposure is less than 1 $\mu W/cm^2$. Figure 5 is a dB plot of the 135 degree radial information giving better detail of the field amplitude values. Figure 6 expands the horizontal scale factor, showing the previous information in the 0–3 mile range.

Ground level field strengths (assuming 100 percent ground reflection) are represented in figure 7 for both WDCA and WETA at 135 degrees. At reasonable distances from the tower, when high depression angle detail is no longer important, it can be seen that though WDCA has approximately four times the ERP of WETA, the calculated field strength is only about twice at great.

The effect of increasing the exposure location height above ground can be seen in figure 8.

Table 2. Calculated field strength and power density for a distance up to 4 miles for WDCA-TV



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FOLLOWING DATA FOR WDCA-TV, WASHINGTON, D.C.
CALCULATED FOR 135 DEGREE RADIAL

MILES          F.S.(V/M)       P.D.(UW/CM.SQ.)F.S.(DB/UV/M)

0               10.2137         27.6712        140.184
.1              8.38176         18.635         138.467
.2              6.04035         9.67793        135.621
.3              4.49883         5.36855        133.062
.4              3.5104          3.26867        130.907
.5              2.8701          2.185          129.158
.6              2.42969         1.56588        127.711
.7              2.09779         1.1673         126.435
.8              1.9325          .990597        125.722
.9              1.70991         .775539        124.659
1               1.51407         .608062        123.603
1.1             1.42997         .542392        123.106
1.2             1.43055         .542834        123.11
1.3             1.28734         .439589        122.194
1.4             1.28813         .440126        122.199
1.5             1.23182         .402486        121.811
1.6             1.39712         .51776         122.905
1.7             1.55025         .637474        123.808
1.8             1.67822         .74706         124.497
1.9             1.59009         .670656        124.028
2.              1.76728         .828459        124.946
2.1             2.00245         1.06361        126.031
2.2             2.24876         1.34135        127.039
2.3             2.15132         1.22763        126.654
2.4             2.37666         1.49828        127.519
2.5             2.28163         1.38086        127.165
2.6             2.19414         1.27699        126.825
2.7             2.4828          1.6351         127.899
2.8             2.39419         1.52046        127.583
2.9             2.31161         1.41738        127.278
3.              2.23456         1.32447        126.984
3.1             2.51702         1.68047        128.018
3.2             2.75983         2.02033        128.818
3.3             2.67623         1.8998         128.55
3.4             2.89567         2.22411        129.235
3.5             2.22962         1.31862        126.964
3.6             2.16757         1.24625        126.719
3.7             2.109           1.17981        126.481
3.8             2.0536          1.11864        126.25
3.9             2.52456         1.69056        128.044
4.              2.46132         1.60692        127.823
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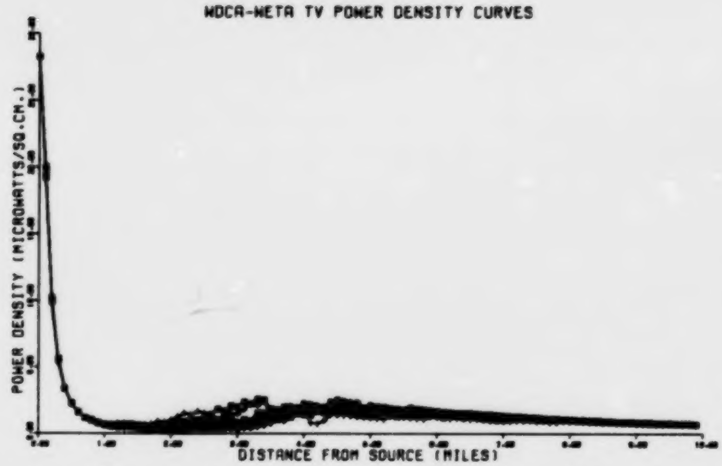

Figure 4. Power density curves along eight radials from WDCA-WETA transmitting antenna

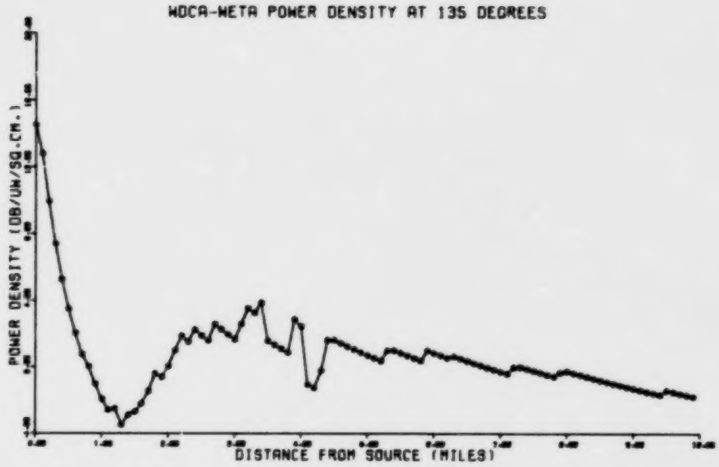

Figure 5. Power density curve along 135 degree radial for WDCA-WETA transmitting antenna (0 to 10 miles)

Separate curves delineate the power density at heights of 0, 100, 200, 300, 400, and 500 feet. The tallest structure in the Washington, D.C. area in which people are allowed is the Washington Monument at 555 feet. Most buildings in the District of Columbia are substantially lower than the Monument. Two buildings very near the WDCA-WETA site, both high-rise apartment buildings, are 143 feet above ground. The buildings are within 0.5 miles of the tower.

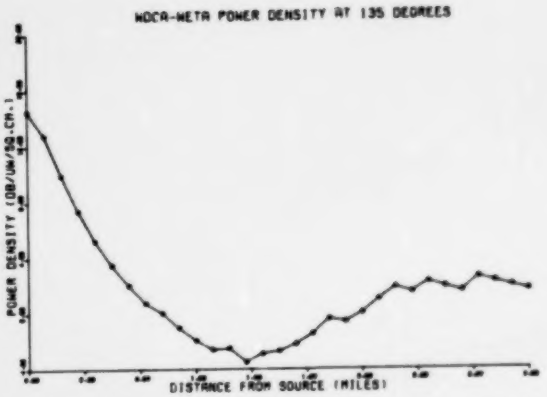

Figure 6. Power density curve along 135 degree radial for WDCA-WETA transmitting antenna (0–3 miles)

Computer generated values for population about the transmitting site were determined on the ITS computer and then the data were reformatted and machine plotted by EPA. Figure 9 shows the results for a distance up to 10 miles from the site. From this curve, it is possible to estimate the number of persons living within various distances for which estimates of RF exposure were made. For the area defined by a 10-mile radius, the population estimate is 1.60 million. Based on 1960 census data, this number was 1.38 million. Within extremely close distance to the site coordinates (0.3 miles), the computed population is 0, due to the fact that the computer program searches for a population centroid with coordinates lying within the given radius. Out to a radius of 0.3 miles from the tower, no population centroids were found. At a radius of 1 mile, however, 19 census enumeration districts (CEDs) had been located. Table 3 is a listing of the number of CEDs within 10 miles at intervals of 1 mile.

Table 3. Census enumeration district distribution

Radius in miles	Number of census enumeration districts
1	19
2	72
3	140
4	221
5	430
6	673
7	894
8	1 132
9	1 313
10	1 497

Discussion and conclusions

The calculated power densities for the WDCA-WETA broadcasting installation show that with the conservative assumptions made in this process, the exposure values fall very sharply (by about 16 dB) as the distance from the site increases to approximately 1 mile. This

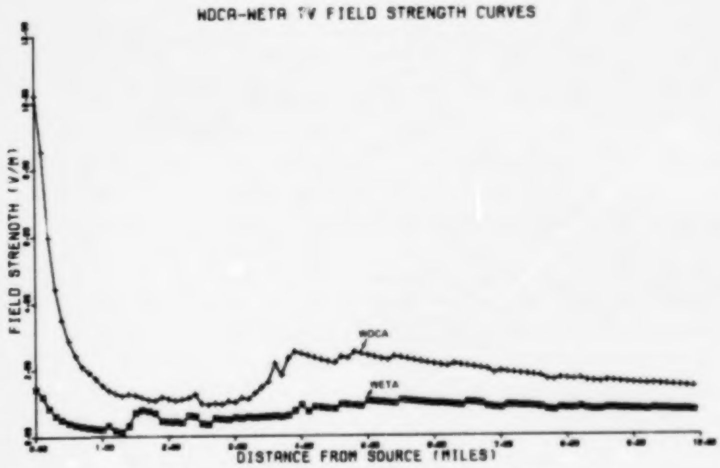

Figure 7. Ground level field strength curves for WDCA-WETA along the 135 degree radial

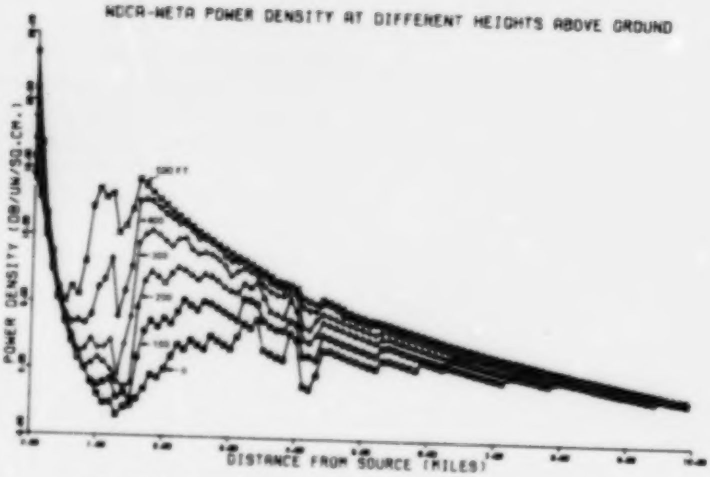

Figure 8. Power density curves for WDCA-WETA transmitting antenna at various heights above ground

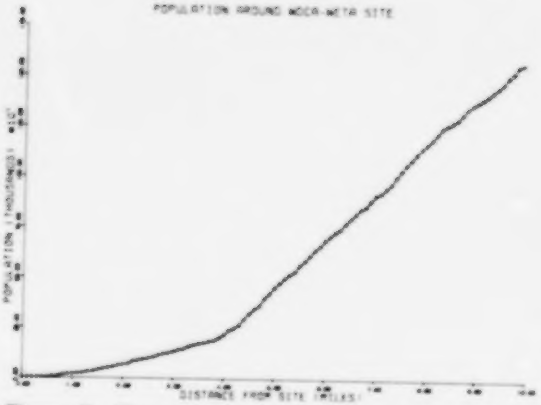

Figure 9. Computer generated values for population around the WDCA-WETA transmitting site

is in accordance with the way the depression angle α varies, α being almost 8 degrees at 1 mile for a tower height of 750 feet (*11*). At this small angle, the relative field factor for both antennas has nearly reached a constant value.

Terrain irregularities account for observable differences in ground level exposures with what appears to be a maximum variation of a factor of 5 at a distance of 3.3 miles. Differences at other distances between individual radial directions are, in general, substantially less. The region of most directional variation in exposure occurs between approximately 2 and 5 miles. At distances beyond 0.5 miles, the maximum exposure values calculated were about 2.7 μW/cm^2 occurring at 0.5, 3.3, and 4.5 miles.

As the height above ground at the receiving point is increased, the exposure value remains fairly constant. Except in the region very near the tower base (i.e., less than 0.5 mile), the distance at which the peak power density occurs increases slightly with decreasing height above ground.

Based on these calculations for the 135 degree radial and the computed population distribution, it appears that approximately 86 000 people reside in an area within which the estimated exposure value is 1 μW/cm^2 or more. It must be borne in mind, though, that these calculations assume perfect ground reflection and no intervening obstacles and thus represent an idealized situation not present in reality. Thus these computed exposure estimates must be used only as a general indication of potential idealized exposure. How far the estimates are in error remains to be determined by actual field measurements. It is known that free space values diverge drastically from actual values in typical environments and as the distance between transmitter and receiver increases. For example, it has been found from field strength measurements of a New York City UHF TV station (channel 31) that actual field values measured on unobstructed roof-tops were typically from 7 to 13 dB (mean value of about 10 dB) down from free space calculated values (no ground reflection assumed) for distances up to about 13 miles (*12*). In fact, in this same study, field strengths which exceeded the free space calculated value were found at only 3 percent of the total 3179 roof-top locations measured. This finding, if applied to values calculated here, would reduce the potential power density exposure levels indicated by a factor of about 1/36. Such a reduction probably places the farther-away values in a more realistic range. Calculated values very near to the source (1 mile) are probably more nearly correct due to lack of intervening terrain clutter.

The attenuating effect of buildings also tends to reduce actual field values substantially. In the above mentioned study, indoor field strength measurements showed field strengths relative to free space in the range of –39 to –47 dB (mean value of about –43 dB) for the UHF channel or an additional perturbation of about 33 dB due to building effects. Other studies of insertion loss effects of buildings show similarly high values of attenuation (*13*).

The essence of these experimental findings indicates that calculated values of field intensity cannot be used to explicitly define whether an RF hazard exists or not; actual field measurements are necessary to verify predictions. Nevertheless, first order approximations can serve to identify areas requiring further investigation. Also, the possibility of complex standing wave configurations resulting in extra intense fields support the more conservative calculational approach until supplementary measurement data are available.

Regardless of the possible error in the values computed here, it is safe to say that, in terms of a direct thermalizing effect of RF (generally associated with exposures greater than 10 mW/cm^2) no areas around the WDCA-WETA site appear to present an RF exposure hazard. The currently accepted RF levels considered safe for continuous occupational exposure are defined in the ANSI (*14*), USAF-Army (*15*), ACGIH (*16*), and OSHA (*17*) standards as 10 mW/cm^2 for the UHF frequency region. Whether these guides should apply to the general populace as a whole has not been decided. The possibility of interference to critical devices, such as cardiac pacers and electroexplosive devices, is a more difficult situation to assess. No standards, per se, exist which define hazardous vs. nonhazardous levels of RF for these devices from an interference standpoint. It has been found that cardiac pacers are apparently more susceptible to pulsed RF fields (similar to radar transmission) than to continuous wave (CW) type fields (similar to TV transmission). However, extensive testing of a variety of pacers indicates that some combinations of CW type signals which produce a rapidly changing electric field gradient can be viewed as "pseudo-pulsed" fields giving rise to pacer interference (*18*). In one case, a pacer failure in the vicinity of a high power UHF TV station has been attributed to the varying amplitude of the station's signal (*1*). It was felt that bursts of detected video modulation or synchronization pulses were not of sufficient length to cause automatic reversion to a fixed pacer rate which is a feature of some pacemakers when exposed to high frequency interference. Fields strengths in the mentioned case were between 0.5 and 1.0 V/m. Additionally, recent unpublished data has revealed disruption of pacemaker operation near the tower of a multistation TV broadcast outlet.[2] Despite possible variabilities in the computed field strength values in this report, fields of these strengths should readily exist within 1 mile of the WDCA-WETA site.

An interesting possibility is brought to light by this exercise; namely that, in the UHF broadcast service, large numbers of people in this country may be routinely exposed to RF fields in excess of 1 μW/cm^2. This is the Soviet standard for nonoccupational exposure in this frequency band (*19*). For Soviet radiation workers, a 10 μW/cm^2 level is permitted for daily exposures of 6–8 hours. Field measurements will be required to verify that routine exposures like this do in fact exist. However, the implication is fairly strong that at least some selected population groups, near the higher power UHF stations are exposed to levels exceeding 1 $\mu W/cm^2$ and thus raises the question of the applicability of the Soviet standard as an environmental exposure limit in the United States.

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[2] Personal communication with J. C. Mitchell, February 16, 1974.

In conclusion, first order approximations to ground level field intensities from a UHF TV broadcast complex have been made for hazard analysis purposes. Though at modest distances from the source, large differences between calculated values and actual values can exist (calculated values being higher), computed values very near the source should be useful for establishing the existence of high-level, thermalizing hazards. In the case examined, under no circumstances can field intensities greater than 28 $\mu W/cm^2$ be envisioned at ground level, this being directly beneath the tower. Since the case considered here represents a combined effective radiated power greater than the maximum possible authorized power for a single UHF TV broadcast station, it is inconceivable that for similar tower heights any single UHF TV station in the U.S. could produce fields greater than those calculated.

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Analysis of Radiation Exposures on or Near Uranium Mill Tailings Piles

Keith J. Schiager[1]

Potential radiation exposures from abandoned uranium mill tailings piles may be predicted in a general manner using minimal input data. If the average radium concentration in the tailings C_{Ra} is known, the external gamma exposure rate over the tailings can be estimated from: X (μR/h) $\cong$ 2.5 C_{Ra} (pCi/g). The radon emanation rate can also be estimated as: ϕ (pCi Rn/m^2–s) $\cong$ 1.6 C_{Ra} (pCi/g). The reductions of exposure rates that can be achieved by covering the tailings with earth or concrete also are discussed. Radon progeny inhalation exposures depend upon the dispersion rate of radon in the atmosphere and the time available for progeny ingrowth. Meteorological data for the site are required for making reliable predictions of inhalation exposures. It is shown, however, that contributions to the average annual outdoor radon progeny concentrations exceeding 0.003 WL are very unlikely on or near any tailings pile. The methods used to analyze potential radiation exposures are illustrated by a case study on one abandoned tailings pile.

Uranium mill tailings piles are a source of potential radiation exposure to persons in the immediate vicinity. During the period of active use, exposures are primarily confined to mill personnel and are classified as occupational. For the purpose of preparing environmental reports, however, mill operators need to predict exposure rates that would occur both during use and also after stabilization. The analytical methods presented herein may be helpful in preparing such environmental reports.

Abandoned tailings piles present some special problems in addition to those encountered with active piles. If left unstabilized, an abandoned pile serves as a continuing source of environmental contamination as a result of wind and water erosion. The cost of stabilization, however, may be a significant economic burden if required of an owner who cannot realize an associated land-use benefit. Furthermore, even a stabilized pile represents a long-term net cost to the community if it cannot be used in some productive manner; the actual cost depends, of course, on the location of the pile and its potential for development.

The construction of enclosed buildings on, or immediately adjacent to, tailings piles is not thoroughly considered in this analysis; such use is not usually an acceptable option. However, data on the effectiveness of concrete slabs for reducing exposures are included since some potential uses of tailings may involve concrete surfacing. These data also can be applied in the analysis of exposures in structures already built over tailings.

Basic principles

The analytical methods presented in this discussion, and the kinds and sources of data required to support the analysis, were determined by the following basic principles.

Short-term stabilization versus long-term risk

At the present time, there is no proven method that is economically feasible for permanently eliminating the possibility of radiation exposures from radium-bearing tailings left on the earth's surface. The half-life of radium-226 is more than 1600 years, and typical uranium mill tailings contain radium concentrations approximately 100 times greater than ordinary Colorado soil (*1,2*). To reduce the radiation exposure potential to a level comparable to the normal background would require a decay time

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of more than 10 000 years. If the thorium-230 precursor of radium-226, with a half-life of 80 000 years, is present in significant quantities, the time element of the argument would be extended accordingly. No human institution, government or private, can effectively guarantee control over any parcel of land for thousands of years.

Any form of control or stabilization, whether by productive development or by nonproductive access restrictions, can be considered valid for only one or two generations. Consequently, any decision on a potential utilization of a tailings site should be based upon the careful appraisal of both the predictable radiation exposures and the expected benefits of the alternative choices over the time period of the anticipated utilization.

Radiation exposure sources

Radium and its decay products can produce radiation exposures through three basic routes; each potential exposure route must be considered independently.

1. Ingestion. Radium may be leached from tailings and enter surface waters or subsurface aquifers. The radium may subsequently be ingested directly with the water or transferred to humans through foods. The obvious preventive measure is to prevent leaching of the tailings. Whether to be used productively or not, a tailings pile should be contoured and covered in a manner that will minimize both leaching and erosion. In general, the risk of radium ingestion will be reduced in direct proportion to the thickness and durability of the cover material used for stabilization. The risk of contamination of water with radium is primarily dependent upon local variables, e.g. topography, soil characteristics, proximity of surface waters and subsurface aquifers, climate, etc. The risk of ingestion cannot be generalized as readily as can the other exposure risks and, consequently, is not considered further here.

2. Inhalation. Radium decays to radon, a noble gas that diffuses readily in air, as well as through many apparently solid materials. The radon that is produced in the uranium decay series is radon-222 which has a half-life of 3.8 days, or a mean lifetime of 5.5 days. During this mean lifetime, a radon atom may be transported hundreds of miles through the atmosphere. However, it would diffuse only a few feet through earth or tailings, and only a few inches through good concrete, during its lifetime.

The inhalation exposure of greatest importance is produced by the short-lived decay products of radon, rather than by the gas itself. Following its decay as radon, an atom progresses through four additional decays in a mean time of 74 minutes, emitting 2 alpha and 2 beta particles in the process. Most of the gamma rays arising from the radium decay series also originate from these short-lived progeny. Inhaled radon progeny atoms can deposit as solid particles in the respiratory tract. Completion of their decay sequence at or near the site of deposition produces a highly localized radiation dose to the respiratory epithelium, particularly due to the short-range alpha particles.

Concentrations of radon progeny in air are commonly expressed in units of working levels (WL)[2]. One WL is equivalent to the radon progeny that would be present in equilibrium with a radon concentration of 100 pCi/liter. Equilibrium in air between radon and its progeny is rarely approached, however, except outdoors at some distance above the ground. Even outdoors, therefore, it is necessary to determine radon progeny concentrations, as opposed to radon only.

3. External. Most of the radon produced by decay of radium is trapped in solid particles. In typical tailings, the "emanating power" (i.e. the fraction of the radon that is free to diffuse) is approximately 20 percent (*1*). The remaining radon (80 percent), plus all of the associated decay products, provide a source of gamma rays from within the tailings.

In contrast with ingestion or inhalation exposures, external gamma rays expose the entire body, including the gonads, blood-forming organs, and other sensitive tissues. However, this source of exposure can be reduced and controlled much more easily than can the emanation of radon. The feasibility of reducing gamma exposure rates essentially to normal background levels is presented in a following section.

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[2] One WL is defined as any combination of radon progeny in 1 liter of air that will result in the ultimate emission of 1.3 × 10^5 MeV of alpha energy during decay to lead-210.

Annual averages

All of the radiation protection guides for the general public are based upon averages over a period of 1 year or longer. For each type of variable exposure, therefore, it is necessary to determine long-term averages rather than relying upon single measurements or peak values. The evaluation of long-term average exposures must include consideration of reasonable annual occupancy factors as well as the variability of the exposure rates. Any radiation exposure situation that involves less than 24 hours/day and 365 days/year of exposure time must be evaluated on the basis of the maximum potential exposure to any individual and the predicted average exposure to a population group.

Simplifying assumptions and approximations

In keeping with the proposed applications of the data and methods which follow, namely to permit reasonably accurate exposure estimates to be made for alternative uses of tailings locations, certain approximations are used to simplify the calculations. Sufficient background information and data are included, however, to support the simplifications. In view of the numerous environmental variables that affect the potential radiation exposures, the use of simplifying assumptions is believed to be justified. The accuracy of the exposure predictions depends much more heavily on the validity of the data introduced into the calculations than it does on the analytical approximations.

Both customary and metric units are used throughout the presentation depending on common usage for the quantity involved. Although all quantities were converted to metric units for purposes of calculation, many customary units were retained in the figures and text for the convenience of readers.

Table 1. Gamma-ray emission and exposure data for radium (*1, 4*)

Number of photons per radium decay	2.184
Total photon energy per radium decay	1.80 MeV
Mean photon energy	.824 MeV
Flux at 1 meter from a 1 curie point source:	
Photon flux	6.4×10^5 photons/cm²−s
Energy flux	5.3×10^5 MeV/cm²−s
Fluence-to-exposure conversions:	
Photon fluence	2 300 photons/cm²−μR
Energy fluence	1 900 MeV/cm²−μR
Gamma-ray exposure constant (for a source sealed in 0.5 mm platinum)	.84 R/h at 1 m from 1 Ci

External gamma-ray exposures

Most tailings sites are sufficiently large that they may be treated as slabs of infinite area for purposes of calculating gamma-ray exposures directly over the surface. The unscattered flux of gamma rays reaching a point near the surface of an infinite slab source can be expressed as (*3*):

$$\Phi = S/2\mu\,[1 - E_2(\mu x)]$$

where: Φ = primary gamma-ray flux (photons/cm²-s)
S = gamma-ray emission rate (photons/cm³-s)
μ = linear attenuation coefficient in the slab material (cm⁻¹)
x = slab thickness (cm)
$E_2(\mu x)$ = second order exponential integral

$$= \mu x \int_{\mu x}^{\infty} e^{-u}\, u^{-2}\, du$$

The radium decay series produces gamma rays over a broad range of energies and relative emission rates. The linear attenuation coefficient, μ, is also energy dependent. Thus, a precise calculation of the unscattered photon flux above the slab would require a summation of the contributions of the gamma rays of each energy. It is possible, however, to obtain reasonably good results using values that have been appropriately averaged for the entire energy spectrum. Some appropriate numerical values are shown in table 1. A graph of the function $[1 - E_2(\mu x)]$ versus μx is shown in figure 1.

Data pertaining to both source terms and shielding functions are listed in table 2. The activity concentration shown for tailings $(C_{Ra}$

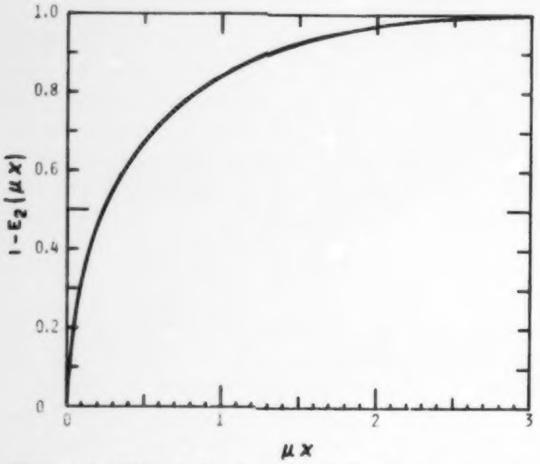

Figure 1. Plot of the function 1-E$_2$ (μx) versus μx

Table 2. Exposure rate variables for environmental radium and radon (values are typical or reasonable averages) (*1*)

Variable	Tailings (dry packed)	Earth (moist packed)	Concrete (ordinary)
Radium concentration, C_{Ra} (pCi/g)	250	2	2
Density, ρ(g/cm^3)	1.6	1.6	2.35
Attenuation coefficient, μ(cm^{-1})	.11	.11	.16
Tenth value layer ($I_x = 0.1\ I_0$)	—	13 inches	9 inches
Porosity (fraction void)	.36	.25	.06
Diffusion coefficient, D(cm^2/s)	5×10^{-2}	5×10^{-2}	2×10^{-3}
Relaxation length, ($C_x = C_0/e$)	1.5 m	1.5 m	5 cm

= 250 pCi/g) is considered typical for the sand portion, although actual concentrations may range from 130 to 300 pCi/g. The radium concentrations shown for earth and concrete are approximations only; actual values generally are in the range of 0 to 10 pCi/g.

Based upon the data contained in tables 1 and 2, one can calculate the emission rate of the unscattered photons:

$$S = (C_{Ra}\ \text{pCi/g})\ (0.037\ \text{dis/s-pCi})\ (1.6\ \text{g/cm}^3)\ (2.184\ \text{photons/dis}) = 0.13\ C_{Ra}\ \text{photons/cm}^3\text{-s}$$

where C_{RA} = concentration of radium in the tailings (pCi/g)

For values of μx greater than 3, the function $[1 - E_2(\mu x)]$ is essentially equal to 1 and the unscattered flux will be the same as that from an infinitely thick slab:

$$\Phi = S/2\mu = (0.13\ C_{Ra}\ \text{photons/cm}^3\text{-s})/2(0.11\ \text{cm}^{-1}) = 0.59\ C_{Ra}\ \text{photons/cm}^2\text{-s}$$

The contribution of the unscattered flux to the exposure rate is then calculated to be:

$$X = (0.59\ C_{Ra}\ \text{photons/cm}^2\text{-s})\ (3600\ \text{s/h})/(2300\ \text{photons/cm}^2\text{-}\mu\text{R}) = 0.92\ C_{Ra}\ \mu\text{R/h}$$

The total exposure rate over the slab, however, is only partially due to unscattered gamma rays. Scattered gamma rays contribute more to the exposure rate over the slab than the primary photons do. It is necessary, therefore, to incorporate a "buildup factor" into the calculations to account for the exposure contribution from the scattered radiation.

Buildup factors can be, and have been, calculated on a theoretical basis, but this approach requires sophisticated data and computerized analyses. The more common approach is to determine the buildup factor empirically by finding the function that best fits the experimental data. Most buildup factors reported in the literature (*3,4*) are applicable to slabs of shielding materials, rather than to slab sources. The following buildup factor is proposed for use in calculations involving tailings piles since it fits the available experimental data quite well:

$$B = e^{\mu x/1+\mu x}$$

Since the value of μ varies from approximately 0.11 cm^{-1} in dry tailings to 0.16 cm^{-1} in concrete, the value of B increases very slowly for x greater than 60 cm, or 24 inches. The values of $[1 - E_2(\mu x)]$ and of B need be determined only if one is concerned with shallow slabs of tailings. For such situations, the graph shown in figure 2 can be used to determine the fraction of the maximum exposure rate that would be produced over the slab. Because of the steep slope of the curve for slab thicknesses of only a few inches, the determination of the slab thickness is crucial for predicting exposure rates over thin layers of tailings.

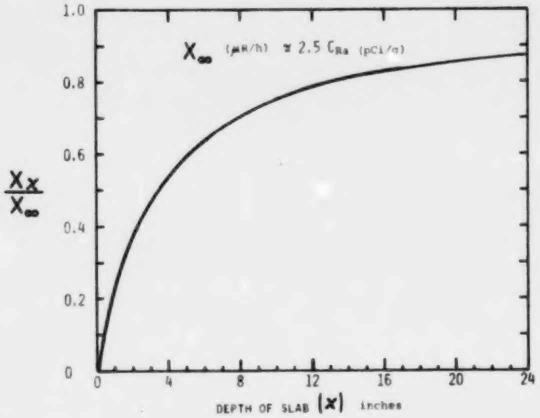

Figure 2. Fractional contribution to gamma exposure rate at surface depth of infinite slab of earth (or tailings) containing radium

For any situation involving tailings depths of more than 1 or 2 feet, the value of μx becomes very large, and the external exposure rate over the tailings can be calculated as follows:

$$X\ (\mu R/h) = 0.92\ e\ C_{Ra}\ (pCi/g) = 2.5\ C_{Ra}\ (pCi/g)$$

The relationship calculated above is in excellent agreement with a simplified formula presented by Hultqvist (5) for determining the dose rate above soils containing radium:

$$D\ (mrads/yr)\ \text{in air} = 18.4 \times 10^{12}\ S\ (g\ Ra/g\ soil)$$

This formula, when converted to the units used in this paper, becomes:

$$X\ (\mu R/h) = \frac{18.4\ (g\text{-}mrad/pCi\text{-}yr)\ C_{Ra}\ (pCi/g)\ 10^3\ (\mu R/mR)}{8766\ (h/yr)\ (0.877\ rad/R)} = 2.4\ C_{Ra}\ (pCi/g)$$

It should be pointed out here that accurate measurements of external gamma-ray exposure rates in the environment are not generally obtained with portable survey instruments. Most instruments are calibrated against point sources exhibiting only the primary photon energy spectrum. Because of the energy dependence of most survey instruments, they tend to over-respond to scattered radiation, which comprises 60 to 70 percent of the total in the environment. Figure 3 shows a calibration curve for a scintillation crystal (NaI) survey meter that was calibrated to read the correct exposure rate when exposed to a point source of radium. In general, readings obtained over tailings locations were more than double the true exposure rate, as determined with a pressurized ioniza-

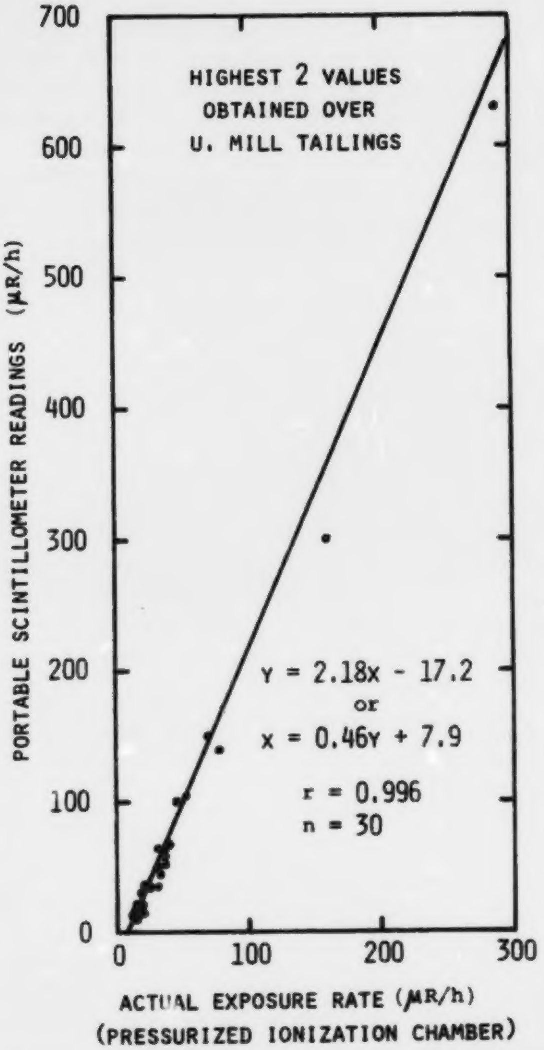

Figure 3. Scintillometer readings versus gamma exposure rate measured with a pressurized ionization chamber at identical locations

tion chamber. Although this calibration applies only to one specific instrument, calibration curves for many other instruments are similar.

Gamma-ray exposures from tailings can be reduced to levels comparable to the natural background by covering with earth to a depth of approximately 2 feet. The reduction factors that can be achieved with various thicknesses of earth or concrete can be determined from the graph in figure 4.

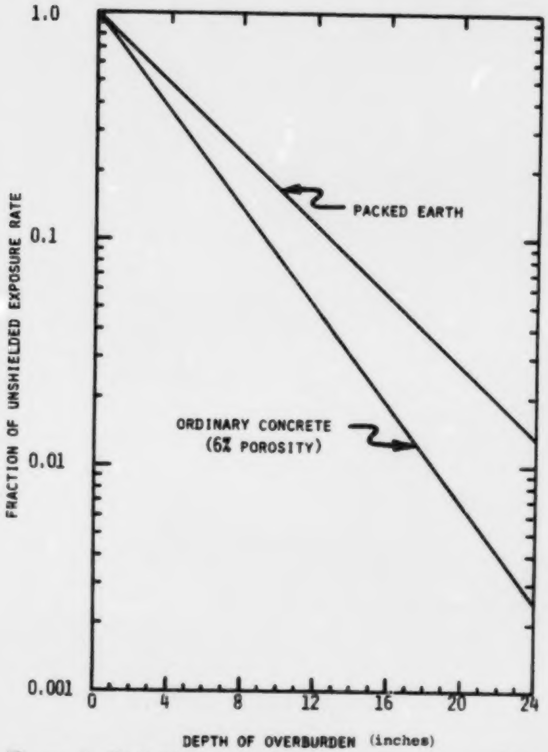

Figure 4. Reduction of gamma exposure rate resulting from earth or concrete shielding (2)

Radon emanation

The rate of radon emanation from a thick slab of uranium mill tailings is primarily dependent on the radium concentration and the fraction of the radon that escapes from the solid particles and is free to diffuse. The radon flux expected at the surface of a slab of dry tailings is shown in figure 5 as a function of slab thickness. The shape of the curve is similar to that which describes the gamma-ray flux; the most notable difference is the scale for the depth of tailings. A slab of 6 to 10 feet in depth is required to produce the maximum radon flux. The relationship between the maximum radon flux and the radium concentration is:

$$\frac{\Phi_\infty \ (\text{pCi Rn/m}^2\text{-s})}{C_{Ra} \ (\text{pCi Ra/g})} = 1.6$$

$$\text{or } \Phi_\infty \ (\text{pCi/m}^2\text{-s}) = 1.6 \ C_{Ra} \ (\text{pCi/g})$$

For tailings depths of only a few feet, the flux can be predicted as a fraction (Φ_x/Φ_∞) of the flux for a slab of infinite thickness, as shown in figure 5.

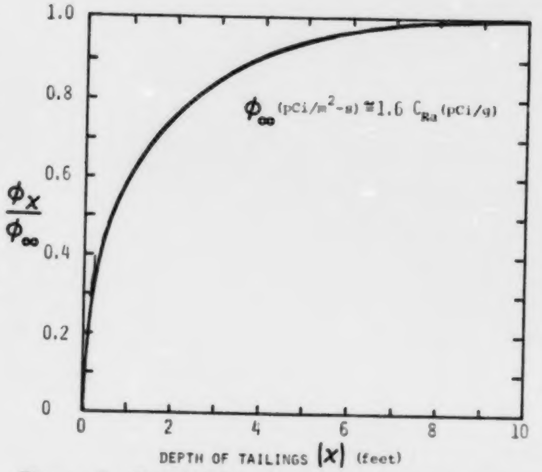

Figure 5. Fractional radon emanation rate versus depth of bare tailings (1)

Radon emanation cannot be stopped as readily with earth as can gamma rays. As shown in table 2, the "relaxation length" (the distance required to reduce the radon concentration by a factor of e) is approximately 1.5 meters of earth, or approximately 10 times greater than the thickness required to reduce the gamma-ray exposure rate by the same factor. Consequently, the thickness of earth cover required to reduce the radon flux to a level equivalent to the normal background would be approximately 20 feet. On the other hand, the diffusion coefficient for radon in concrete is approximately three orders of magnitude smaller than it is in earth. The

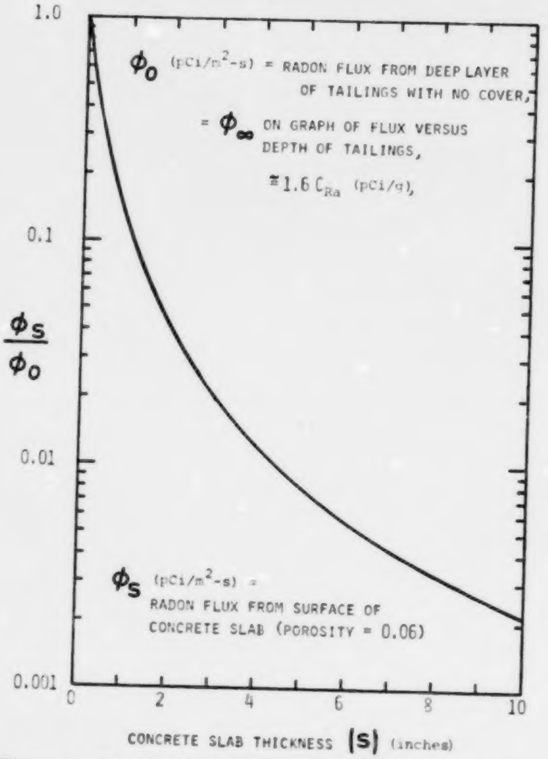

Figure 6. Fractional radon emanation rate through concrete slab placed over a thick layer of tailings versus slab thickness (*1*)

relaxation length is correspondingly shorter (5 cm or 2 inches), indicating the potential of using concrete slabs to reduce radon diffusion, as shown in figure 6.

Radon progeny ingrowth

The concentration of radon in the atmosphere depends upon the rate of dispersion as well as upon the rate of emanation into the atmosphere. The actual inhalation exposure, however, is determined by the concentration of radon progeny which is also dependent upon the mean "age" of the radon. Evans (*6*) has presented a detailed but concise analysis of the behavior of radon progeny. The radon progeny concentration per unit concentration of radon, for ingrowth times up to 12 minutes, starting with radon contamination only, is shown in figure 7.

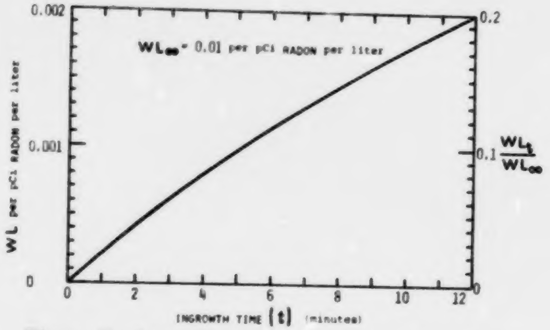

Figure 7. Ingrowth rate of radon progeny from radon-222 (in units of working levels, WL)

For typical tailings piles of several hundred meters in width, and typical wind speeds of a few meters per second, the transit time over the tailings is rarely more than a few minutes. Thus, the ingrowth of radon progeny in the immediate vicinity of the pile can seldom exceed 10 percent of its equilibrium value, or 0.001 WL per pCi of radon per liter. The maximum concentration of radon progeny, under most meteorological conditions, would occur just beyond the edge of the pile; further downwind, the dilution of the radon in the atmosphere more than compensates for the subsequent ingrowth of the progeny.

In the special situation in which buildings are located immediately adjacent to a tailings pile, the indoor radon concentration in such buildings would be in equilibrium with that found outdoors. The residence time of the air indoors would be long enough, however, for the radon progeny to reach a significant fraction of the equilibrium concentration. It is highly likely that the radon progeny concentration in a building adjacent to, but not on, a tailings pile would be higher than the maximum outdoor concentration. Such situations obviously require more detailed evaluations.

Atmospheric dispersion

The method used to calculate the concentration and mean age of radon in the atmosphere is shown in figure 8. The method is based on one important assumption: that the lateral extent of the area source (tailings), upwind

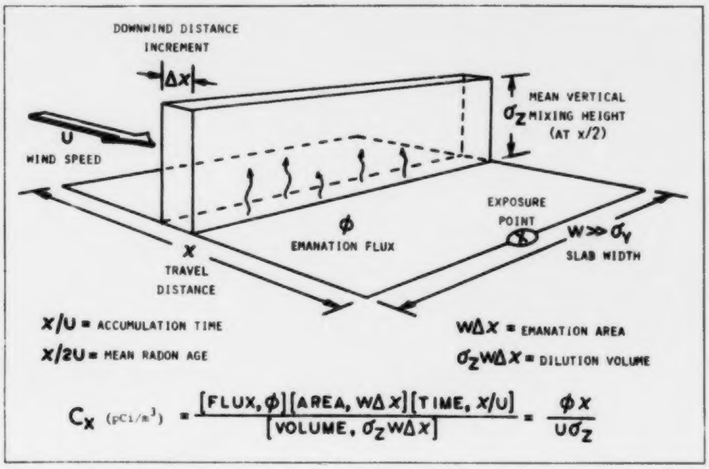
DOWNWIND DISTANCE INCREMENT
Δx
U
WIND SPEED
MEAN VERTICAL
σz MIXING HEIGHT
(AT x/2)
φ
EMANATION FLUX
EXPOSURE POINT
w>>σy
SLAB WIDTH
x
TRAVEL DISTANCE
x/u = ACCUMULATION TIME
x/2u = MEAN RADON AGE
wΔx = EMANATION AREA
σzwΔx = DILUTION VOLUME
Cx (pCi/m³) = [FLUX, φ][AREA, wΔx][TIME, x/u] / [VOLUME, σz wΔx] = φx / uσz

Figure 8. Atmospheric dilution diagram for radon emanating from a large slab source, e.g., a tailings pile

from the point where the concentration is to be determined, is large compared to the horizontal dispersion coefficient for the assumed meteorological condition. This assumption will always be satisfied if the width of the upwinding tailings area, w, is of the same order of magnitude as the travel distance in the direction of the wind, x.

Horizontal and vertical dispersion coefficients, σ_y and σ_z, represent the mean mixing distances, for various meteorological conditions, as functions of the downwind travel distance (7). For the stated assumption, i.e. $w >> \sigma_y$, the actual value of σ_y is not required for the analysis to be made here. However, the value of σ_z is crucial; values of σ_z for x in the range of 100 to 1000 meters are plotted in figure 9.

Consider a thin section of air extending across the tailings slab in a direction normal to the wind. The area of this section of air at the slab surface is wΔx, where Δx is a small increment of distance in the direction of the wind, and w is the width of the slab. The height of this section of air is assumed to be the mean vertical mixing height, σ_z, at the mean travel distance, x/2.

The total distance in the direction of the wind, from the upwind edge of the source area to the point where the concentration is to be determined, is defined as x. At a wind speed of u, the total time available for accumulation of radon in the section of air is x/u; the mean radon age is x/2u.

The radon concentration is calculated as follows:

$$C_{Rn}\ (\mathrm{pCi/m^3}) = \frac{[\phi\ (\mathrm{pCi/m^2\text{-}s})]\ [w\Delta x\ (\mathrm{m^2})]\ [x/u\ (\mathrm{s})]}{[w\Delta x \sigma_z\ (\mathrm{m^3})]}$$

$$= \phi x/u\sigma_z\ (\mathrm{pCi/m^3})$$

$$= 10^{-3}\ \phi x/u\sigma_z\ (\mathrm{pCi/liter})$$

The preceding calculation applies strictly to instantaneous conditions and to locations on or immediately adjacent to a tailings pile. The concentration at a distance, d, further downwind from the tailings pile, may be estimated from:

$$C_{Rn}\ (\text{at } x+d) = C_{Rn}\ (\text{at } x)\ \frac{\sigma_y\sigma_z\ (\text{at } x)}{\sigma_y\sigma_z\ (\text{at } x+d)}$$

In this case, the mean travel time, or the mean age of the radon, would be (d+x/2)u. Beyond the range for which this calculation is valid, the radon concentration will be too low to be of much interest.

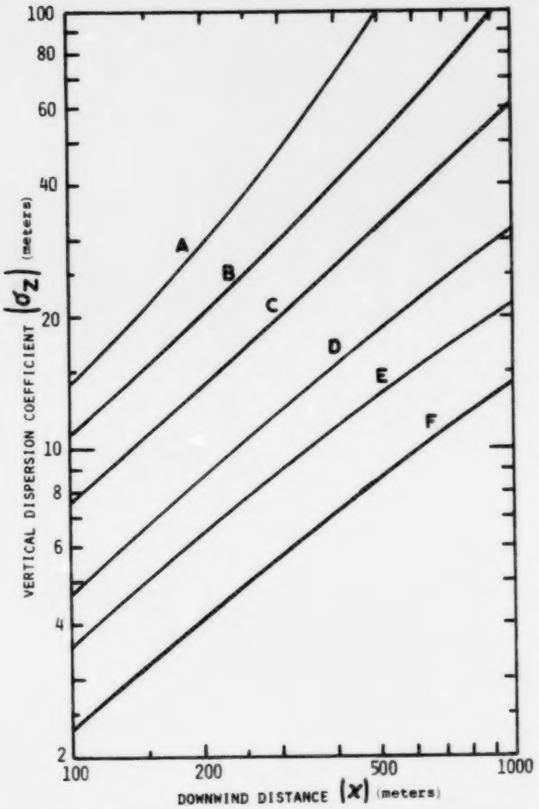

Figure 9. Vertical dispersion coefficients by atmospheric stability classes (after Pasquill and Gifford) (7)

Case study—the Vitro site

The data and computations which follow are presented as a case study to illustrate procedures for predicting radiation exposures that might be encountered as a result of commercial development of a uranium mill tailings pile. This case was selected because it involved a specific proposal by the Silvex Corporation of Salt Lake City to construct an automobile race track on the site of the abandoned tailings pile of the Vitro Chemical Corporation near Salt Lake City. The average radium concentration in this pile has been estimated to be 290 pCi/g.

The general layout of the tailings pile from the Vitro mill, and the location of the proposed Silvex Speedway, is shown in figure 10. The general wind pattern, as reported by Shearer and Sill (*8*), is shown on the site plan. The prevailing wind, occurring approximately half of the time, is from the south-southeast. The most frequent wind direction is from the northwest; it is referred to as the "Salt Lake City" wind, and occurs about 20 percent of the time. A "morning" wind from the south occurs somewhat less frequently.

The estimated distribution of tailings over the 93-acre site is listed in table 3. The source terms for calculating potential radiation exposures are contained in table 4. The gamma-ray exposure rate of 1.1 mR/h over the bare tailings was measured with CaF_2:Dy thermoluminescent dosimeters (*8*). The source used in the calibration of these dosimeters was not specified. The radon emanation rates were calculated in the manner previously presented.

Exposure calculations

The specific assumptions used in the calculation of radon and radon progeny concentrations also are shown in figure 10. The most important exposure location was assumed to be the proposed track. Since the largest source of radon lies to the southwest of the track, the SSE prevailing wind was assumed. The radon flux in the upwind area (cross-hatched) was assumed to be 350 pCi/m^2-s.

Because of a lack of specific meteorological data, three atmospheric stability conditions (B, D, and F), and three wind speeds for each stability class, were assumed. A frequency of occurrence, based upon generalizations from other locations, was assigned to each meteorological condition. Since the calculations were made only for the prevailing wind direction, the frequencies of occurrence were selected to produce a total of 100 percent, although the actual frequencies for this wind direction would be only 50 percent of the total. For the indicated wind direction, the mean source distance, x, is 1400 feet (460 meters).

The intermediate results obtained from the atmospheric dispersion and concentration calculations are shown in table 5. The calculated average radon concentration, for the stated assumptions, turned out to be 6.8 pCi/liter, com-

Table 3. Estimated distribution of tailings on old Vitro mill site

Area	Quantity of tailings				
	Acres	M (tons)	M (cubic yards)	Average depth (feet)	Exposed area (m^2)
Silvex proposal:					
Track	[a]13.5	0.33	0.13	14	21 000
North parking	[a]10.3	.27	.11	5.5	42 000
South parking	[a]10.1	.26	.10	5.5	41 000
Subtotal	33.9	0.86	[b]0.34	8.9	104 000
Other:					
Vacant (north)	12.5				
South frontage	5.2	.16	.06	3.1	72 000
M & R	41.4	.48	.20	3.1	167 000
Total	[b]93	[b]1.5	0.6	5.2	343 000

[a] Areas determined from architect's drawings for Silvex Speedway. All other numbers are estimates derived from (a) and (b) and from personal observations.

[b] Personal communication from Mr. Robert J. Catlin, USAEC, April 11, 1973.

Table 4. Radiation exposure source terms for Vitro mill site

Site area [a]	Average tailings depth (feet)	Exposed area (m^2)	Bare tailings exposures		Assumed earth cover	Covered tailings	
			Radon (pCi/m^2-s)	Gamma (mR/h)		Radon (pCi/m^2-s)	Gamma (mR/h)
Vacant (north)	3.1	51 000	380	1.1	1 foot earth	350	0.1
North parking	5.5	42 000	435	1.1	2 feet earth	360	.01
Track:							
Bowl	0	—	—	—	none	0	.01
Grandstands	14	—	—	—	2 feet earth + 9 inches concrete	<1	.01
Surroundings	14	21 000	455	1.1	2 feet earth	380	.01
South parking	5.5	41 000	435	1.1	2 feet earth	360	.01
South frontage	3.1	21 000	380	1.1	2 feet earth	310	.01
M & R	3.1	167 000	380	1.1	1 foot earth	350	.1

[a] Designated areas are as shown in figure 10.

Table 5. Calculations of average concentrations of radon and progeny

Radon flux, ϕ: 350 pCi/m^2-s
Source distance, X: 1400 feet or 460 m

Atmospheric stability class: Vertical dispersion coefficient, σ_z (at $X/2$):	B, good dispersion 23 m			D, neutral 9.5 m			F, near stagnant 4.5 m		
Wind speed, μ: (miles per hour)	6.7	13.4	20.0	4.5	9.0	13.5	2.2	4.5	6.7
(m/s)	3.0	6.0	9.0	2.0	4.0	6.0	1.0	2.0	3.0
Frequency of occurrence (assumed), f:	.10	.10	.05	.20	.20	.20	.05	.05	.05
Radon concentration: $C_i = (10^{-3}) \phi x / u \sigma_z$: (pCi/liter)	2.3	1.2	.80	8.5	4.2	2.8	36	18	12
Contribution to annual average, $C_f = fC_i$: (pCi/liter)	.23	.12	.04	1.7	.84	.56	1.8	.90	.60
Radon progeny concentration: Ingrowth time, $x/2u$: (s)	77	38	26	115	58	38	230	115	77
(min)	1.3	.6	.4	1.9	1.0	.4	3.8	1.9	1.3
Progeny ingrowth fraction, WL per pCi Rn/liter: [$\times 10^4$]	2.8	1.3	1.0	4.0	2.2	1.0	7.6	4.0	2.8
$WL_i = (WL\text{-}1/pCi)C_i$: [$\times 10^4$]	6.4	1.6	.8	34	9.2	2.8	270	72	33
Contribution to annual average, $WL_f = fWL_i$: [$\times 10^4$]	.64	.16	.05	6.8	1.8	.56	14	3.6	1.7

Annual averages (calculated from above assumptions):
Radon, C(average) = ΣCf = 6.8 pCi/liter
Radon progeny, WL(average) = Σ WL_f = 0.0029 WL
Average radon progeny ingrowth = 0.0029/6.8 = 0.00043, or 4 percent of equilibrium.

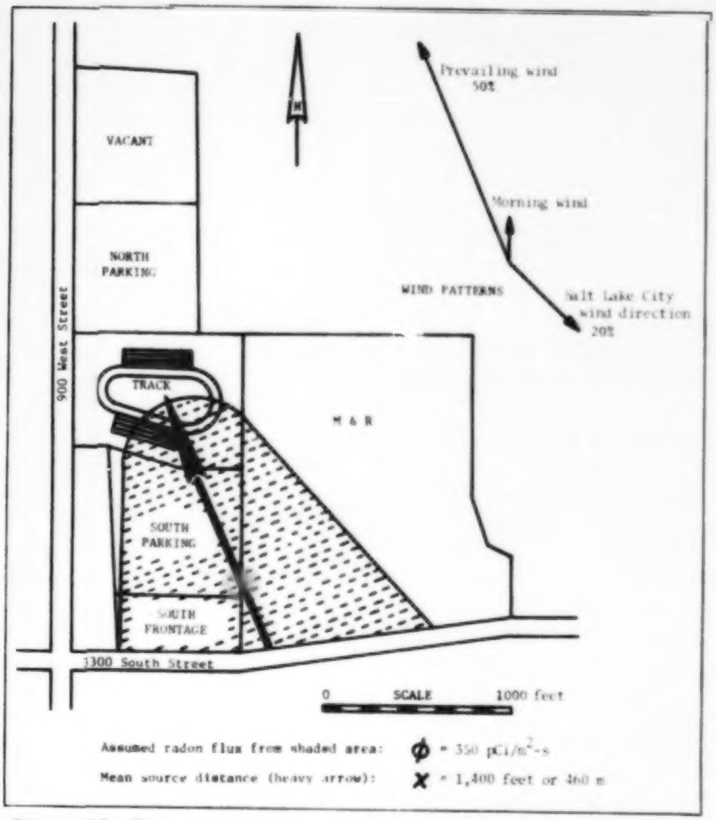
Prevailing wind
50%
N
VACANT
Morning wind
NORTH
PARKING
WIND PATTERNS
Salt Lake City
wind direction
20%
900 West Street
TRACK
M & R
SOUTH
PARKING
SOUTH
FRONTAGE
1300 South Street
0 SCALE 1000 feet
Assumed radon flux from shaded area: ϕ = 350 pCi/m^2-s
Mean source distance (heavy arrow): X = 1,400 feet or 460 m

Figure 10. Radon source geometry for prevailing wind at proposed Silvex Speedway

pared with a measured value (*8*) of 10 pCi/liter. The calculated average concentration of radon progeny is 0.0029 WL.

At least two potential sources of error in the theoretical analysis of radon exposures should be noted:

(1) Errors in the assumed meteorological conditions. Although the mean wind speed used in the calculations (9 miles per hour) is essentially the same as that observed during the period of the radon measurements (*8*), the assumed dispersion conditions may not be adequately representative. Also, the use of only the prevailing wind direction in the calculations tends to produce an overestimate of the average radon concentration.

(2) Errors in the assumed radon flux. The radon emanation rate used in the calculations was based upon experimental data obtained with dry tailings. The radon flux can be lowered significantly if the tailings are soaked and/or covered with standing water.

Although the numerical values used in the calculations were carried to two or three figures, the resulting exposure estimates should be interpreted as valid only to one significant figure, with an estimated overall accuracy of approximately a factor of two.

Occupancy factors

Radiation protection guides for the general public are always based on annual averages and not on instantaneous peak values. In the case of the proposed Silvex Speedway, the automobile racing season would be limited to about 5 months—primarily by the temperature range that is acceptable to spectators in outdoor grandstands. For the foreseeable future, the track proposed to schedule events no more than three nights a week; however, it is possible that it might eventually be used as many as six evenings each week. In addition, a few special events, e.g. snowmobile racing, could be scheduled during the winter. The maximum number of track use days could conceivably be 150 per year.

The average time that most spectators will remain at any sporting event is generally 4 hours or less. Consequently, the maximum public attendance time at the track might be as high as 600 hours, although the average exposure time would obviously be much less. A full-time employee at the track would be exposed a maximum of 2000 hours per year, although fewer hours would be more likely.

Enclosed structures

The most significant type of radiation exposure produced by uranium mill tailings, and the most difficult and costly to control, is the exposure to airborne radon progeny in enclosed spaces. If a structure is built in direct contact with tailings, it is possible for radon to diffuse directly from the tailings into the structure. If a structure is merely situated in an environment containing abnormally high atmospheric radon concentrations, the indoor concentration of radon will be essentially equal to the outdoor concentration.

The critical factor in determining the indoor radon progeny concentration, in addition to ascertaining the concentration of the radon, is the assessment of the mean residence time of the radon in the indoor atmosphere. In private homes, the typical air residence time falls in the range of 20 to 60 minutes. In commercial structures, the average time for one complete air exchange is frequently less than 20 minutes.

In the case of the proposed Silvex Speedway, the only enclosed areas would be the snack bars, the rest rooms, a press box and a club house. Each of these structures would have to be designed in a manner that would minimize the buildup of radon and progeny. The direct diffusion of radon into these structures from tailings beneath them could be minimized by using extra thick concrete floor slabs, or even multilayered floors with radon barriers between the layers.

Even with radon barriers in the floors, the indoor radon concentrations would be in equilibrium with the outdoor concentrations. During occupancy, ingrowth of radon progeny might have to be minimized by reducing the mean air residence time indoors to a few minutes, or by continually recirculating and filtering the air. These precautions would be needed for the benefit of track employees who would be spending much more time indoors than the race spectators. However, since the situation could be evaluated prior to construction, the radon progeny exposures could be controlled appropriately.

Radiation dose limits and population risk

There is no recognized radioactivity concentration guide (RCG) for radon alone, nor is there a radiation protection guide (RPG) for the general population for the type of radiation exposure of concern here. However, there are three acceptable sources of recommended exposure limits from which inferences may be drawn. Each of the recommended exposure limits is based upon the dose to the respiratory tract from the alpha particles emitted by the short-lived progeny, but each is restricted to occupational exposures or to a special situation.

The ICRP (*9*) recommends a limit for continuous occupational exposure of 10 pCi of radon per liter of air, including all of the daughter products ordinarily found in unfiltered air. Depending upon the degree of equilibrium, this limit would be equivalent to 0.03 to 0.1 WL. The ICRP further recommends that the average permissible limit for the population at large should not exceed one-thirtieth of the continuous occupational value. Although the phrase "populations at large" is not precisely defined, the continuous public exposure limit recommended by the ICRP could be as low as 0.001 to 0.003 WL.

In connection with the anticipated remedial action program for buildings in Grand Junction, Colo. (where tailings had been used as construction fill), exposure guidelines were set by the U.S. Surgeon General (*10*). The Surgeon General's guidelines state that for an annual average exposure of less than 0.001 WL, no corrective action is indicated. This limit, of course, was set only for a preexisting exposure condition and is not directly applicable to a preplanned situation. However, if this limit is reduced by another factor of three to account for a general, as opposed to a limited, population, the annual average exposure limit would be equivalent to the ICRP value, or 0.003 WL.

The third exposure limit from which an inference may be drawn is that recommended by the Federal Radiation Council (*11*) and subsequently adopted by the U.S. Department of Labor. This limit applies to uranium miners and is expressed as an annual exposure limit of 4 WL-months per year. Since one month of occupational exposure consists of 173 hours, this is equal to an exposure-time product of 692 WL-hours per year. If this limit is reduced by the factor of 30 recommended by the ICRP, the resulting limit for the general population becomes, by inference, about 23 WL-hours per year. If this number is divided by 8766 hours/year, the average annual exposure limit would also be 0.003 WL.

Whether or not the occupational exposure limit for radon progeny inhalation should be reduced for the general population by the same factor as is applied to other kinds of radiation exposure is a matter of conjecture. In a comprehensive analysis of the incidence of lung cancer among uranium miners, Lundin et al. (*12*) found no indication of additional risk among miners having a cumulative exposure of less than 120 WL-months. Spread out over a nominal 70-year lifetime, rather than the 30 years used in deriving the occupational limit, the equivalent continuous exposure rate would be 0.03 WL. Radon progeny inhalation may, in fact, be one type of exposure for which there is a practical, if not theoretical, threshold for somatic biological effects.

Since all of the recommended exposure limits are for exposures in addition to natural background radiation, the natural concentrations of radon and its progeny must be considered. Eisenbud (*13*) states that "the average concentrations of radon in outdoor air may be taken to be in the range of 0.1 to 0.5 pCi/liter and the radon concentration inside buildings is somewhat higher and in round numbers may be taken as 0.5 pCi/liter on the average." In a study of radon in ground level air at Cincinnati, Ohio, Cox et al. (*14*) found that monthly average concentrations ranged from 0.1 to 1.5 pCi/liter during an 8-year period. Radon progeny concentrations in outdoor air, measured in Colorado, are typically in the range of 0.001 to 0.01 WL, with a mean of about 0.004 WL.

Conversion of all of the calculated exposures and inferred exposure limits to common units of WL-hours per year permits the following comparisons:

Naturally occurring radon progeny, outdoors:
0.004 WL × 8766 h/yr = 35 WL-h/yr

Occupational exposure limit for uranium miners:
4 WL-mo/yr × 173 h/mo = 692 WL-h/yr

Inferred population exposure limit (in addition to natural background):
0.003 WL × 8766 h/yr = 26 WL-h/yr

Full-time race track employees (maximum):
0.003 WL × 2000 h/yr = 6 WL-h/yr

Individual spectators (maximum):
0.003 WL × 600 h/yr = 2 WL-h/yr

At present there is no consensus on the appropriate conversion of working-level-months to man-rems or any other acceptable units of population dose commitment. However, it can be pointed out that if the track were to be completed as proposed, a few full-time employees would receive an exposure increment of 17 percent above the normal background exposure, corresponding to 1 percent of the occupational exposure limit, or 23 percent of the population exposure limit. A few thousand members of the general public could receive a maximum additional exposure of 6 percent over the natural background or about 8 percent of the inferred population exposure limit.

Conclusions

For a depth of tailings of more than 1 or 2 feet thick, the gamma exposure rate over the tailings can be estimated from:

$$X\,(\mu R/h) \cong 2.5\, C_{Ra}\,(pCi/g)$$

Since C_{Ra} refers to a uniform concentration of radium in the tailings, it is essential that the value of C_{Ra} used in the above calculation be representative of the pile as a whole. Nonuniformity of the radium concentration would produce variations in measured exposure rates over the pile, but would have minimal effects on long-term average exposures.

The gamma-ray exposure rate over a tailings pile can be reduced to essentially that of the normal background by a cover of 2 feet of packed earth.

The radon emanation rate from the surface of a dry, bare tailings pile several feet thick can be estimated from:

$$\phi_{\infty}\ (pCi/Rn/m^2\text{-}s) \cong 1.6\, C_{Ra}\ (pCi\ Ra/g)$$

Air concentrations of radon will be highest at the downwind edge of the pile. Earth covering will not be very effective for reducing radon emanation; 2 feet of earth would only reduce the radon flux to about three-fourths of its initial value.

The air concentration of radon progeny, the determinant factor for inhalation exposures, depends upon both the concentration and the mean age of the radon. For typical piles and wind conditions, the ingrowth of radon progeny near the pile will rarely reach 10 percent of equilibrium with the maximum radon concentration. It is also unlikely that the outdoor radon progeny concentration, on or near any tailings pile, would exceed an annual average of 0.003 WL in addition to natural background.

All of the radon and radon progeny concentrations presented in this paper were calculated on the basis of very conservative assumptions. To the extent possible, the calculations should be verified and refined. Air sampling for radon progeny concentrations, even for a relatively short time period, would provide some experimental evidence of actual conditions. A refinement of the theoretical analysis could also be made by using actual meteorological data for the local area instead of the assumed conditions used in the preceding calculations.

Enclosed structures should not be constructed on, or adjacent to, tailings piles without valid assurances that the occupancy factors will be quite low. Even then, special attention must be given to construction plans, and especially to ventilation, to assure low indoor air residence times during the periods of occupancy.

Until a permanent solution is found to the problem of abandoned uranium mill tailings, any plans for stabilization or utilization must be regarded as valid for only a short time period, e.g. 25–50 years. Although denial of all public access to a tailings pile may be a convenient and expedient action for a regulatory agency (*15–17*), it has not been conclusively demonstrated to be in the best public interest in all cases. If a productive use is proposed for an abandoned tailings location, a detailed analysis should be made of the potential radiation exposures involved. It is apparent that, in some circumstances, the radiation exposure risk would be extremely low and might well be completely offset by the benefits to be derived from productive use.

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SECTION I. MILK AND FOOD

Milk Surveillance, February 1974

Although milk is only one of the sources of dietary intake of environmental radioactivity, it is the food item that is most useful as an indicator of the general population's intake of radionuclide contaminants resulting from environmental releases. Fresh milk is consumed by a large segment of the population and contains several of the biologically important radionuclides that may be released to the environment from nuclear activities. In addition, milk is produced and consumed on a regular basis, is convenient to handle and analyze, and samples representative of general population consumption readily can be obtained. Therefore, milk sampling networks have been found to be an effective mechanism for obtaining information on current radionuclide concentrations and long-term trends. From such information, public health agencies can determine the need for further investigation or corrective public health action.

The Pasteurized Milk Network (PMN) sponsored by the Office of Radiation Programs, Environmental Protection Agency, and the Office of Food Sanitation, Food and Drug Administration, Public Health Service, consists of 65 sampling stations: 63 located in the United States, one in Puerto Rico, and one in the Canal Zone. Many of the State health departments also conduct local milk surveillance programs which provide more comprehensive coverage within the individual State. Data from 15 of these State networks are reported routinely in *Radiation Data and Reports*. Additional networks for the routine surveillance of radioactivity in milk in the Western Hemisphere and their sponsoring organizations are:

Pan American Milk Sampling Program (Pan American Health Organization and U.S. Environmental Protection Agency)—5 sampling stations

Canadian Milk Networks (Radiation Protection Division, Canadian Department of National Health and Welfare)—16 sampling stations.

The sampling locations that make up the networks reporting presently in *Radiation Data and Reports* are shown in figure 1. Based on the similar purpose for these sampling activities, the present format integrates the complementary data that are routinely obtained by these several milk networks.

Radionuclide and element coverage

Considerable experience has established that relatively few of the many radionuclides that are formed as a result of nuclear fission become incorporated in milk (*1*). Most of the possible radiocontaminants are eliminated by the selective metabolism of the cow, which restricts gastrointestinal uptake and secretion into the milk. The five fission-product radionuclides which commonly occur in milk are strontium-89, strontium-90, iodine-131, cesium-137, and barium-140. A sixth radionuclide, potassium-40, occurs naturally in 0.0118 percent (*2*) abundance of the element potassium, resulting in a specific activity for potassium-40 of 830 pCi/g total potassium.

Two stable elements which are found in milk, calcium and potassium, have been used as a means for assessing the biological behavior of metabolically similar radionuclides (radiostron-

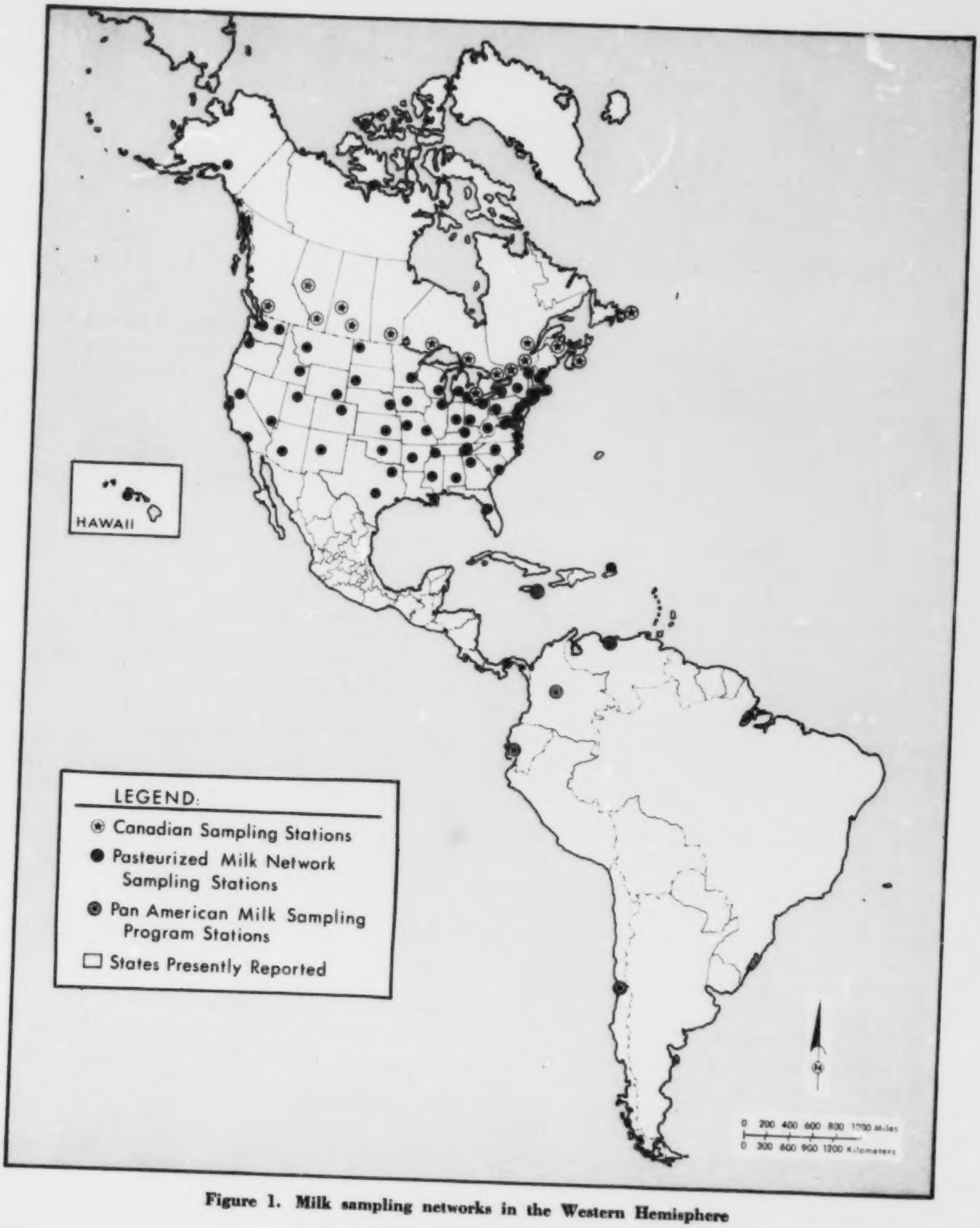
HAWAII
LEGEND:
⊛ Canadian Sampling Stations
● Pasteurized Milk Network Sampling Stations
⊙ Pan American Milk Sampling Program Stations
☐ States Presently Reported
N
0 200 400 600 800 1000 Miles
0 300 600 900 1200 Kilometers

Figure 1. Milk sampling networks in the Western Hemisphere

tium and radiocesium, respectively). The contents of both calcium and potassium in milk have been measured extensively and are relatively constant. Appropriate values and their variations, expressed in terms of 2 standard deviations (2σ), for these elements are 1.16 ± 0.08 g/liter for calcium and 1.51 ± 0.21 g/liter for potassium. These figures are averages of data from the PMN for May 1963-March 1966 (*3*) and are used for general radiation calculations.

Accuracy of data from various milk networks

In order to combine data from the international, national, and State networks considered in this report, first it was necessary to determine the accuracy with which each laboratory is making its determinations and the agreement of the measurements among the laboratories. The Analytical Quality Control Service of the Research and Development Program conducts periodic studies to assess the accuracy of determinations of radionuclides in milk performed by interested radiochemical laboratories. The generalized procedure for making such a study has been previously outlined (*4*).

The most recent study was conducted during June 1972 with 37 laboratories participating in an experiment on a milk sample containing known concentrations of iodine-131, cesium-137, strontium-89, and strontium-90 (*5*). Of the 18 laboratories producing data for the network reports in *Radiation Data and Reports*, 14 participated in the study.

The accuracy results of this study for these 14 laboratories are shown in table 1. The accuracy of the cesium-137 measurements continues to be excellent as in previous experiments. However, both the accuracy and precision need to be improved for iodine-131, strontium-89, and strontium-90 which could probably be accomplished through recalibration.

Development of a common reporting basis

Since the various networks collect and analyze samples differently, a complete understanding of several parameters is useful for interpreting the data. Therefore, the various milk surveillance networks that report regularly were surveyed for information on analytical methods, sampling and analysis frequencies, and estimated analytical errors associated with the data.

In general, radiostrontium is collected by an ion-exchange technique and determined by beta-particle counting in low-background detectors, and the gamma-ray emitters (potassium-40, iodine-131, cesium-137, and barium-140) are determined by gamma-ray spectroscopy of whole milk. Each laboratory has its own modifications and refinements of these basic methodologies.

Many networks collect and analyze samples on a monthly basis. Some collect samples more frequently but composite the several samples for one analysis, while others carry out their analyses more often than once a month. Many networks are analyzing composite samples on a quarterly basis for certain nuclides. The fre-

Table 1. Distribution of mean results, quality control experiment

Isotope and known concentration		Number of laboratories in each category				Experimental 2σ error (pCi/liter)
		Acceptable [a]	Warning level [b]	Unacceptable [c]	Total	
Iodine-131:	(96 or 99 pCi/liter)	7 (58%)	1 (8%)	4 (33%)	12	6
	(438 or 484 pCi/liter)	11 (85%)	0	2 (15%)	13	25 or 28
Cesium-137:	(53 or 54 pCi/liter)	11 (92%)	0	1 (8%)	12	6
	(295 or 303 pCi/liter)	11 (85%)	2 (15%)	0	13	17
Strontium-89:	(29 or 30 pCi/liter)	9 (82%)	0	2 (18%)	11	6
	(197 or 201 pCi/liter)	3 (33%)	1 (11%)	5 (56%)	9	11 or 12
Strontium-90:	(32.1 or 32.4 pCi/liter)	4 (33%)	4 (33%)	4 (33%)	12	1.9
	(150.5 or 151.2 pCi/liter)	6 (55%)	0	5 (45%)	11	8.7

[a] Measured concentration equal to or within 2σ of the known concentration.
[b] Measured concentration outside 2σ and equal to or within 3σ of the known concentration.
[c] Measured concentration outside 3σ of the known concentration.

quency of collection and analysis varies not only among the networks but also at different stations within some of the networks. In addition, the frequency of collection and analysis is a function of current environmental levels. The number of samples analyzed at a particular sampling station under current conditions is reflected in the data presentation. Current levels for strontium-90 and cesium-137 are relatively stable over short periods of time, and sampling frequency is not critical. For the short-lived radionuclides, particularly iodine-131, the frequency of analysis is critical and generally is increased at the first measurement or recognition of a new influx of this radionuclide.

The data in table 2 show whether raw or pasteurized milk was collected. An analysis (*6*) of raw and pasteurized milk samples collected during January 1964 to June 1966 indicated that for relatively similar milkshed or sampling areas, the differences in concentration of radionuclides in raw and pasteurized milk are not statistically significant (*6*). Particular attention was paid to strontium-90 and cesium-137 in that analysis.

Practical reporting levels were developed by the participating networks, most often based on 2-standard-deviation counting errors or 2-standard-deviation total analytical errors from replicate analyses (*3*). The practical reporting level reflects analytical factors other than statistical radioactivity counting variations and will be used as a practical basis for reporting data.

The following practical reporting levels have been selected for use by all networks whose practical reporting levels were given as equal to or less than the given value.

Radionuclide	Practical reporting level (pCi/liter)
Strontium-89	5
Strontium-90	2
Iodine-131	10
Cesium-137	10
Barium-140	10

Some of the networks gave practical reporting levels greater than those above. In these cases, the larger value is used so that only data considered by the network as meaningful will be presented. The practical reporting levels apply to the handling of individual sample determinations. The treatment of measurements equal to or below those practical reporting levels for calculation purposes, particularly in calculating monthly averages, is discussed in the data presentation.

Analytical error of precision expressed as pCi/liter or percent in a given concentration range also has been reported by the networks (*3*). The precision errors reported for each of the radionuclides fall in the following ranges:

Radionuclide	Analytical errors of precision (2 standard deviations)
Strontium-89	1–5 pCi/liter for levels <50 pCi/liter; 5–10% for levels ≥50 pCi/liter;
Strontium-90	1–2 pCi/liter for levels <20 pCi/liter; 4–10% for levels ≥20 pCi/liter;
Iodine-131 Cesium-137 Barium-140	4–10 pCi/liter for levels <100 pCi/liter; 4–10% for levels ≥100 pCi/liter.

For iodine-131, cesium-137, and barium-140, there is one exception for these precision error ranges: 25 pCi/liter at levels <100 pCi/liter for Colorado. This is reflected in the practical reporting level for the Colorado milk network.

Federal Radiation Council guidance applicable to milk surveillance

In order to place the United States data on radioactivity in milk in perspective, a summary of the guidance provided by the Federal Radiation Council for specific environmental conditions was presented in the February 1973 issue of *Radiation Data and Reports.*

Data reporting format

Table 2 presents the integrated results of the international, national, and State networks discussed earlier. Column 1 lists all the stations which are reported routinely in *Radiation Data and Reports.* The relationship between the PMN stations and the State stations is shown in

Table 2. Concentrations of radionuclides in milk for February 1974 and 12-month period March 1973 through February 1974

Sampling location		Type of sample [a]	Radionuclide concentration (pCi/liter)			
			Strontium-90		Cesium-137	
			Monthly average [b]	12-month average	Monthly average [b]	12-month average
UNITED STATES:						
Ala:	Montgomery[c]	P	NA	4	0	3
Alaska:	Palmer[c]	P	NA	4	0	1
Ariz:	Phoenix[c]	P	NA	0	0	0
Ark:	Little Rock[c]	P	NA	11	0	1
Calif:	Los Angeles[c]	P	NA	0	0	0
	Sacramento[c]	P	NA	1	0	0
	San Francisco[c]	P	NA	0	0	0
	Del Norte	P	NA		NA	
	Fresno	P	NA		NA	
	Humboldt	P	NA		NA	
	Los Angeles	P	NA		NA	
	Mendocino	P	NA		NA	
	Sacramento	P	NA		NA	
	San Diego	P	NA		NA	
	Santa Clara	P	NA		NA	
	Shasta	P	NA		NA	
	Sonoma	P	NA		NA	
Colo:	Denver[c]	P	NA	3	[d] 0	0
	East	R	NS	NA	NS	23
	Northeast	R	NS	NA	NS	0
	Northwest	R	NS	NA	NS	2
	South Central	R	NS	NS	NS	NS
	Southeast	R	NS	NA	NS	0
	Southwest	R	NA	NA	[d] 0	0
	West	R	NS	NA	NS	0
Conn:	Hartford[c]	P	NA	4	0	2
	Central	P	NA		NA	
Del:	Wilmington[c]	P	NA	6	0	1
D.C:	Washington[c]	P	NA	8	0	0
Fla:	Tampa[c]	P	NA	4	17	24
	Central	R	6	5	19	24
	North	R	7	6	13	15
	Northeast	R	6	6	27	26
	Southeast	R	5	5	68	48
	Tampa Bay area	P	4	5	18	27
	West	R	NA	8	NA	8
Ga:	Atlanta[c]	P	NA	4	0	3
Hawaii:	Honolulu[c]	P	NA	0	0	0
Idaho:	Idaho Falls[c]	P	NA	3	0	0
Ill:	Chicago[c]	P	NA	5	0	0
Ind:	Indianapolis[c]	P	NA	5	0	2
	Central	P	4	5	0	6
	Northeast	P	6	5	0	10
	Northwest	P	7	7	0	9
	Southeast	P	5	6	0	8
	Southwest	P	6	7	0	6
Iowa:	Des Moines[c]	P	NA	4	0	0
	Des Moines	P	5	5	0 (3)	0
	Iowa City	P	5	5	0	0
	LeMars	P	4	4	0	0
	Little Cedar	P	7	6	0	0
Kans:	Wichita[c]	P	NA	5	0	1
	Coffeyville	P	7	6	0	7
	Dodge City	P	4	4	0	6
	Falls City, Nebr	R	NS	6	NS	7
	Hays	P	7	6	0	5
	Kansas City	P	3	4	0	6
	Topeka	P	6	6	0	5
	Wichita	P	4	6	20	8
Ky:	Louisville[c]	P	NA	5	0	1
La:	New Orleans[c]	P	NA	7	0	1
Maine:	Portland[c]	P	NA	4	0	12
Md:	Baltimore[c]	P	NA	6	0	3
Mass:	Boston[c]	P	NA	7	0	8
Mich:	Detroit[c]	P	NA	6	0	3
	Grand Rapids[c]	P	NA	7	0	1
	Bay City	P	10	11	0	1
	Charlevoix	P	11	9	7	2
	Detroit	P	9	8	0	0
	Grand Rapids	P	22	12	0	3
	Lansing	P	11	11	0	3
	Marquette	P	18	11	6	7
	Monroe	P	7	13	0	1
	South Haven	P	21	14	3	3
Minn:	Minneapolis[c]	P	NA	7	0	1
	Bemidji	P	6	6	0	0
	Duluth	P	13	16	12	23
	Fergus Falls	P	5	5	0	0
	Little Falls	P	6	16	0	23
	Mankato	P	5	5	0	0
	Marshall	P	0	3	0	0

See footnotes at end of table.

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Table 2. Concentrations of radionuclides in milk for February 1974 and 12-month period March 1973 through February 1974—continued

Sampling location		Type of sample [a]	Radionuclide concentration (pCi/liter)			
			Strontium-90		Cesium-137	
			Monthly average [b]	12-month average	Monthly average [b]	12-month average
Minn:	Minneapolis	P	9	8	0	0
	Rochester	P	3	6	0	0
Miss:	Jackson[c]	P	NA	8	0	6
Mo:	Kansas City[c]	P	NA	4	0	0
	St.Louis[c]	P	NA	8	0	1
Mont:	Helena[c]	P	NA	2	0	0
Nebr:	Omaha[c]	P	NA	2	0	0
Nev:	Las Vegas[c]	P	NA	5	0	0
N.H:	Manchester[c]	P	NA	6	0	7
N.J:	Trenton[c]	P	NA	5	0	1
N. Mex:	Albuquerque[c]	P	NS	0	NS	0
N.Y:	Buffalo[c]	P	NA	5	0	3
	New York City[c]	P	NA	4	0	2
	Syracuse[c]	P	NA	6	0	1
	Albany	P	4	4	0	0
	Buffalo	P	2	4	0	0
	Massena	P	9	7	15	10
	New York City	P	4	7	0	0
	Syracuse	P	2	5	NA	0
N.C:	Charlotte[c]	P	NA	7	0	4
N. Dak:	Minot[c]	P	NA	6	0	0
Ohio:	Cincinnati[c]	P	NA	5	0	3
	Cleveland[c]	P	NA	6	0	2
Okla:	Oklahoma City[c]	P	NA	3	0	0
Oreg:	Portland[c]	P	NA	4	0	1
	Baker	P	NA	NA	0	1
	Coos Bay	P	NA	NA	0	1
	Eugene	P	NA	NA	0	0
	Medford	P	NA	NA	0	0
	Portland composite	P	NA	NA	0	1
	Portland local	P	NA	NA	0	2
	Redmond	P	NA	NA	0	0
	Tillamook	P	NA	NA	0	4
Pa:	Philadelphia[c]	P	NA	5	0	1
	Pittsburgh[c]	P	NA	9	0	3
	Dauphin	P	5	5	0	0
	Erie	P	7	7	0	0
	Philadelphia	P	5	4	0	0
	Pittsburgh	P	6	5	0	0
R.I:	Providence[c]	P	NA	4	0	4
S.C:	Charleston[c]	P	NS	5	NS	6
	Chapin	R	NS	8	NS	9
	Clemson	R	8	8	5	10
	Columbia	R	NS	8	NS	9
	Fairfield	R	NS	7	NS	12
	Hartsville-02	R	6	6	10	10
	Hartsville-03	R	14	15	13	13
	Lee County	R	NS	0	NS	14
	Oconee County	R	7	7	4	6
	Pickens	R	NS	7	4	6
	Williston	R	NS	7	NS	17
	Winnsboro	R	NS	7	NS	17
	York-01	R	7	7	6	6
	York-02	R	5	5	0	0
S. Dak:	Rapid City[c]	P	NS	6	0	1
Tenn:	Chattanooga[c]	P	NA	6	0	1
	Knoxville[c]	P	NA	0	0	0
	Memphis[c]	P	NA	6	0	2
	Chattanooga	P	NA	7	0	5
	Clinton	R	6	6	0	5
	Fayetteville	R	8	7	0	5
	Kingston	R	6	7	0	3
	Knoxville	P	5	5	0	4
	Lawrenceburg	R	6	6	0	4
	Nashville	P	NA	5	0	2
	Pulaski	R	5	6	0	2
	Sequoyah	R	NS	9	NS	5
Tex:	Austin[c]	P	NA	0	0	0
	Dallas[c]	P	NA	4	0	0
Utah:	Salt Lake City[c]	P	NA	2	0	0
Vt:	Burlington[c]	P	NA	4	0	5
Va:	Norfolk[c]	P	NA	6	0	1
Wash:	Seattle[c]	P	NA	1	0	0
	Spokane[c]	P	NA	5	0	0
	Benton County	R	NS	0	NS	0
	Franklin County	R	0	0	0	0
	Longview	R	6	5	16	7
	Sandpoint, Idaho	R	4	5	0	1
	Skagit County	R	3	4	0	0
W. Va:	Charleston[c]	P	NA	7	0	2
Wisc:	Milwaukee[c]	P	NA	4	0	1
Wyo:	Laramie[c]	P	NA	1	0	1

See footnotes at end of table.

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Table 2. Concentrations of radionuclides in milk for February 1974 and 12-month period March 1973 through February 1974—continued

Sampling location		Type of sample [a]	Radionuclide concentration (pCi/liter)			
			Strontium-90		Cesium-137	
			Monthly average [b]	12-month average	Monthly average [b]	12-month average
CANADA:						
Alberta:	Calagary	P	NA		5	7
	Edmonton	P	NA		6	11
British Columbia:	Vancouver	P	NA		9	12
Manitoba:	Winnipeg	P	NA		9	9
New Brunswick:	Moncton	P	NA		7	9
Newfoundland:	St. John's	P	NA		8	15
Nova Scotia:	Halifax	P	NA		6	9
Ontario:	Ottawa	P	NA		4	5
	Sault Ste. Marie	P	NA		9	15
	Thunder Bay	P	NA		8	10
	Toronto	P	NA		5	5
	Windsor	P	NA		4	5
Quebec:	Montreal	P	NA		5	7
	Quebec	P	NA		10	12
Saskatchewan:	Regina	P	NA		5	7
	Saskatoon	P	NA		5	7
CENTRAL AND SOUTH AMERICA:						
Canal Zone:	Cristobal[c]	P	NS	0	NS	9
Chile:	Santiago	P	2	0	0	0
Colombia:	Bogota	P	2	1	0	0
Ecuador:	Guayaquil	P	0	1	0	0
Jamaica:	Mandeville	P	NS	2	NS	23
Puerto Rico:	San Juan[c]	P	NA	3	0	2
Venezuela:	Caracas	P	0	1	0	2
PMN network average[e]			NA	4	0	2

[a] P, pasteurized milk.
R, raw milk.

[b] When an individual sampling result was equal to or less than the practical reporting level, a value of "0" was used for averaging. Monthly averages less than the practical reporting level reflect the fact that some but not all of the individual samples making up the average contained levels greater than the practical reporting level. When more than one analysis was made in a month period, the number of samples in the monthly average is given in parentheses.

[c] Pasteurized Milk Network station. All other sampling locations are part of the State or National network.

[d] The practical reporting level for this network differs from the general ones given in the text. Sampling results for these networks were equal to or less than the following practical reporting levels:
Cesium-137: Colorado—25 pCi/liter; Oregon—15 pCi/liter.

[e] This entry gives the average radionuclide concentrations for the Pasteurized Milk Network stations denoted by footnote [c].
NA, no analysis.
NS, no sample collected.

figure 2. The first column in table 2 under each of the reported radionuclides gives the monthly average for the station and the number of samples analyzed in that month in parentheses. When an individual sampling result is equal to or below the practical reporting level for the radionuclide, a value of zero is used for averaging. Monthly averages are calculated using the above convention. Averages which are equal to or less than the practical reporting levels reflect the presence of radioactivity in some of the individual samples greater than the practical reporting level.

The second column under each of the radionuclides reported gives the 12-month average for the station as calculated from the preceding 12 monthly averages, giving each monthly average equal weight. Since the daily intake of radioactivity by exposed population groups, averaged over a year, constitutes an appropriate criterion for the case where the FRC radiation protection guides apply, the 12-month average serves as a basis for comparison.

Discussion of current data

In table 2, surveillance results are given for strontium-90 and cesium-137 for February 1974 and the 12-month period, March 1973 to February 1974. Except where noted, the monthly

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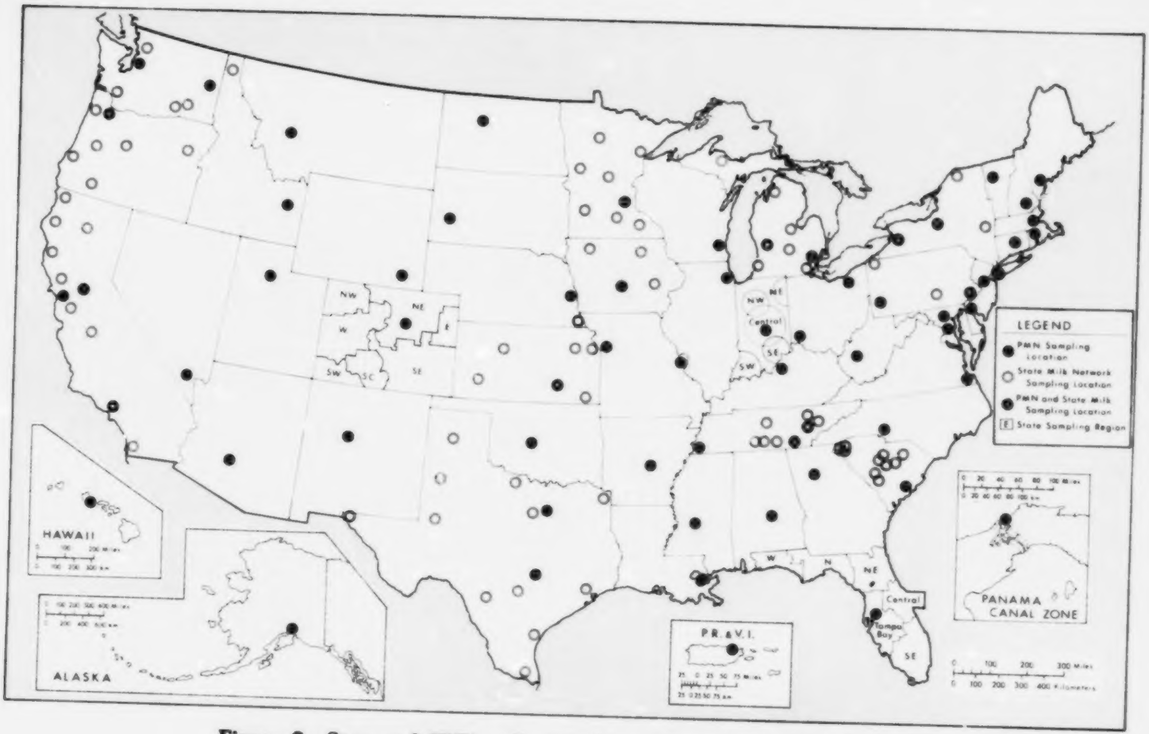
LEGEND
PMN Sampling Location
State Milk Network Sampling Location
PMN and State Milk Sampling Location
E State Sampling Region
NW
NE
W
SW
SC
SE
E
Central
N
Tampa Bay
HAWAII
ALASKA
P.R. & V.I.
PANAMA CANAL ZONE

Figure 2. State and PMN milk sampling stations in the United States

average represents a single sample for the sampling station. Strontium-89, iodine-131, and barium-140 data have been omitted from table 2 since levels at all of the stations for February 1974 were below the respective practical reporting levels.

Strontium-90 monthly averages ranged from 0 to 22 pCi/liter in the United States for February 1974 and the highest 12-month average was 16 pCi/liter (Duluth and Little Falls, Minn.) representing 8.0 percent of the Federal Radiation Council radiation protection guide. Cesium-137 monthly averages ranged from 0 to 68 pCi/liter in the United States for February 1974, and the highest 12-month average was 48 pCi/liter (Southeast Florida) representing 1.3 percent of the value derived from the recommendations given in the Federal Radiation Council report.

The Office of Radiation Programs is in the process of modifying the milk program to make it more responsive to potential sources of environmental radioactivity. These changes will be reflected in future articles.

Acknowledgement

Appreciation is expressed to the personnel of the following agencies who provide data from their milk surveillance networks:

Radiologic Health Section
Environmental Control Component
California Department of Health

Radiation Protection Bureau
Canadian Department of National Health and Welfare

Radiological Health Section
Division of Occupational and Radiological Health
Colorado Department of Health

Laboratory Division
Connecticut Department of Health

Radiological and Occupational Health Section
Department of Health and Rehabilitative Services
State of Florida

Bureau of Environmental Sanitation
Division of Sanitary Engineering
Indiana State Board of Health

Division of Radiological Health
Environmental Engineering Services
Iowa State Department of Health

Radiation Control Section
Environmental Health Division
Kansas State Department of Health

Radiological Health Services
Division of Occupational Health
Michigan Department of Health

Radiation Control Section
Division of Environmental Health
State of Minnesota Department of Health

Bureau of Radiological Pollution Control
New York State Department of Environmental Conservation

Environmental Radiation Surveillance Program
Division of Sanitation and Engineering
Oregon State Board of Health

Radiological Health Section
Bureau of Environmental Health
Pennsylvania Department of Public Health

Division of Radiological Health
South Carolina Department of Health and Environmental Control

Radiological Health Services
Division of Preventable Diseases
Tennessee Department of Public Health

Division of Occupational Health
Environmental Health Services
Texas State Department of Health

Radiation Control Unit
Health Services Division
Washington Department of Social and Health Services

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(*2*) U.S. ATOMIC ENERGY COMMISSION, DIVISION OF ISOTOPES DEVELOPMENT. Chart of the Nuclides, Tenth Edition revised to December 1968. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402.

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(*4*) ROSENSTEIN, M. and A. S. GOLDIN. Statistical technics for quality control of environmental radioassay. Health Lab Sci 2:93 (April 1965).

(*5*) BARATTA, E. J. and F. E. KNOWLES, JR. Interlaboratory study of iodine-131, cesium-137, strontium-89, and strontium-90 measurements in milk, June 1972, Technical experiment 72 MKAQ–1. Analytical Quality Control Service, Office of Radiation Programs, EPA, Washington, D.C. 20460 (December 1972).

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Food and Diet Surveillance

Efforts are being made by various Federal and State agencies to estimate the dietary intake of selected radionuclides on a continuing basis. These estimates, along with the guidance developed by the Federal Radiation Council, provide a basis for evaluating the significance of radioactivity in foods and diet.

Networks presently in operation and reported routinely include those listed below. These networks provide data useful for developing estimates of nationwide dietary intakes of radionuclides. Programs reported in *Radiation Data and Reports* are as follows:

Program	Period reported	Issue
California Diet	July 1971–December 1972	February 1974
Carbon-14 in Total Diet and Milk	1972–1973	November 1973
Strontium-90 in Tri-City Diets	1972	December 1973

SECTION II. WATER

The Environmental Protection Agency and other Federal, State, and local agencies operate extensive water quality sampling and analysis programs for surface, ground, and treated water. Most of these programs include determinations of gross beta and gross alpha radioactivity and specific radionuclides.

Although the determination of the total radionuclide intake from all sources is of primary importance, a measure of the public health importance of radioactivity levels in water can be obtained by comparison of the observed values with the Public Health Service Drinking Water Standards (*1*). These standards, based on consideration of Federal Radiation Council (FRC) recommendations (*2–4*) set the limits for approval of a drinking water supply containing radium-226 and strontium-90 at 3 pCi/liter and 10 pCi/liter, respectively. Higher concentrations may be acceptable if the total intake of radioactivity from all sources remains within the guides recommended by FRC for control action. In the known absence[1] of strontium-90 and alpha-particle emitters, the limit is 1000 pCi/liter gross beta radioactivity, except when additional analysis indicates that the concentrations of radionuclides present are not likely to cause exposures greater than the limits indicated by the Radiation Protection Guides. Surveillance data from a number of Federal and State programs are published periodically to show current and long-range trends. Water sampling activities reported in *Radiation Data and Reports* are listed below.

Water sampling program	Period reported	Issue
California	1971 and 1972	November 1973
Colorado River Basin	1968	March 1972
Community Water Supply Study	1969	September 1972
ERAMS Surface Water and Drinking Water Components	October–December 1973	June 1974
Florida	1970	April 1974
Interstate Carrier Drinking Water	1971	May 1972
Kansas	1971	February 1973
Minnesota	July 1971–June 1972	March 1974
New York	January–December 1972	June 1974
Radiostrontium in Tap Water, *HASL*	January–December 1972	December 1973
Washington	July 1970–June 1971	August 1973

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[1] Absence is taken to mean a negligibly small fraction of the specific limits of 3 pCi/liter and 10 pCi/liter for unidentified alpha-particle emitters and strontium-90, respectively.

REFERENCES

(*1*) U.S. PUBLIC HEALTH SERVICE. Drinking water standards, revised 1962, PHS Publication No. 956. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (March 1963).

(*2*) FEDERAL RADIATION COUNCIL. Radiation Protection Guidance for Federal Agencies. Memorandum for the President. September 1961. Reprint from the Federal Register of September 26, 1961.

(*3*) FEDERAL RADIATION COUNCIL. Background material for the development of Radiation Protection Standards, Report No. 1. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (May 1960).

(*4*) FEDERAL RADIATION COUNCIL. Background material for the development of Radiation Protection Standards, Report No. 2. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (September 1961).

Radioactivity in North Carolina Surface, Cistern, and Saline Waters, 1971[1]

Sanitary Engineering Division
Radiological Health Section
North Carolina State Board of Health[2]

The North Carolina State Board of Health maintains an Environmental Radiation Surveillance Network to monitor radioactivity in selected media throughout the State. The Program is administered by the Radiological Health Section of the Sanitary Engineering Division.[2] Sample analysis is provided by the Environmental Sciences Section of the Laboratory Division. The Public Health Statistics Section of the Epidemiology Division provides assistance in certain data processing activity, while computer services are obtained through the Systems Management Division of the Department of Administration. Environmental sample collection is performed primarily by the staffs of municipalities and local health departments.

The program started with the surveillance of 147 sources of untreated surface waters. These supplies were selected as being representative of water quality in the many river basins of the State. Sample collection was achieved through close cooperation with municipalities and local health departments.

The program has changed through the years as technological advances in instrumentation made it possible to monitor more facets of the environment. In July 1962, cistern water samples from Ocrocoke Island were added to the surveillance program. In January 1963, airborne particulates, rainfall, and dustfall samples were collected on a routine sampling schedule over the State. The surface water program was modified to include treated water assays. Public ground water supplies also were added to the sampling program during this period.

Surface water

Grab samples of both treated and untreated surface water are taken on a monthly basis at nine water treatment plants. These stations

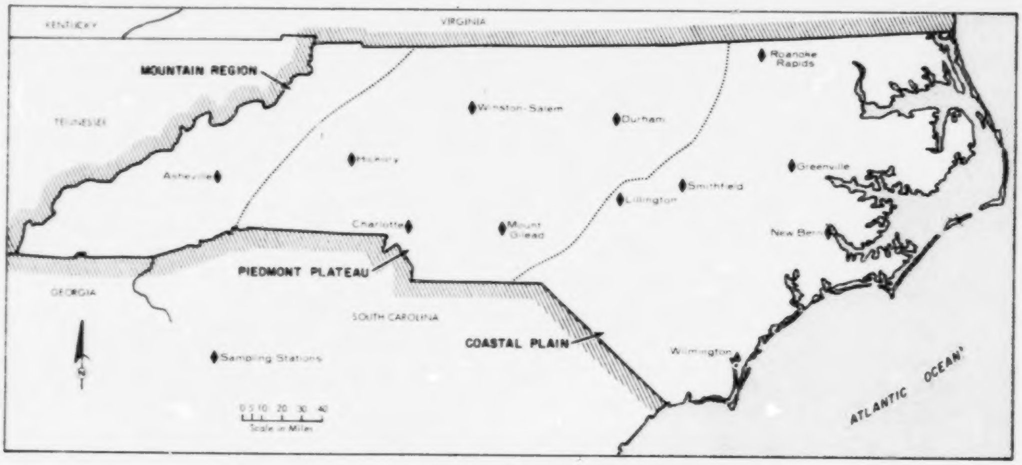
KENTUCKY
VIRGINIA
MOUNTAIN REGION
TENNESSEE
Roanoke Rapids
Winston-Salem
Durham
Hickory
Asheville
Greenville
Smithfield
Lillington
Charlotte
Mount Gilead
New Bern
PIEDMONT PLATEAU
GEORGIA
SOUTH CAROLINA
COASTAL PLAIN
Wilmington
Sampling Stations
N
0 5 10 20 30 40
Scale in Miles
ATLANTIC OCEAN

Figure 1. North Carolina water sampling stations, 1971

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[1] Summarized from "Environmental Radiation Surveillance in North Carolina, 1971."

[2] As of April 1974, Radiation Protection Branch, Division of Facility Services, North Carolina Department of Human Resources.

were selected to obtain samples from the State's major drainage districts with the French-Broad, Catawba, Yadkin, Cape Fear, Neuse, and Tar-Pamlico river basins being represented.

The samples routinely are collected in 1-gallon (polyethylene) containers by the water plant operator or chemist and mailed to the State laboratory for analysis. Additional samples can be collected as needed. These stations are shown in figure 1.

Untreated water samples are acidified with hydrochloric acid to prevent loss of activity through precipitation and/or adhesion. The samples then are transferred to 3½-liter polyethylene Marinelli beakers for gamma scans.

After scanning, 1 liter is filtered through Whatman No. 12 folded filter paper. The filter paper, containing the suspended solids, is ashed in a muffled furnace at 600 degrees Celsius. The residue then is transferred to a tared planchet, dried, weighed, and submitted for gross alpha and beta counting (*1*).

The filtrate is separated by precipitation into dissolved sulfates and dissolved carbonates, plancheted, and submitted for gross beta counting (*1*).

If the total gross beta is greater than 5 pCi/liter, a strontium-89 and strontium-90 determination is performed (*1*).

As with the untreated surface water, treated water samples are acidified with 2 milliliters of hydrochloric acid to prevent loss of activity through precipitation and adhesion. These samples are transferred to 3½-liter polyethylene Marinelli beakers for gamma scans. The suspended material is prepared for gross alpha and beta counting in the same manner as untreated water samples. The filtrate carefully is evaporated to determine the gross alpha and beta activity of the dissolved solids. As before, if

Table 1. Gross beta radioactivity in North Carolina raw surface water, January-December 1971

Month (1971)	Raw water (pCi/liter)										
	Ash-ville	Hickory	New Bern	Winston-Salem	Roanoke Rapids	Lilling-ton	Smith-field	Char-lotte	Mt. Gilead	Wilm-ington	Green-ville
January	ND	4.00			4.40	ND	ND	ND	ND	ND	ND
February	<3.0	4.00		14.50	ND	7.30	ND	3.30	4.10	7.00	9.40
March	<3.0	ND		<3.0	5.10	5.60	7.40	3.30	5.20	6.80	5.60
April	<3.0	<3.0		<3.0	4.60	7.50	4.50	3.90	5.00	ND	5.30
May	<3.0	3.70		10.30	ND	7.20	7.90	4.80	4.90	6.10	8.40
June	<3.0	ND	9.50	5.80	ND	6.10	5.70	<3.0	6.50	7.30	7.30
July	<3.0	<3.0	21.70	4.40	4.30	6.00	6.50	<3.0	4.50	6.70	6.90
August	<3.0	<3.0	23.10	3.10	4.20	6.90	5.70	<3.0	4.20	4.30	6.10
September	<3.0	ND	7.20	<3.0	ND	7.00	6.20	<3.0	3.90	4.20	6.20
October	<3.0	<3.0	5.40	3.70	3.70	5.80	5.70	<3.0	4.90	4.40	6.50
November	<3.0	3.10	6.20	<3.0	ND	4.10	ND	ND	4.60	34.80	ND
December	ND	<3.0	ND	<3.0	ND	4.30	5.00	<3.0	3.10	3.00	3.70

ND, Nondetectable.

Table 2. Gross beta radioactivity in North Carolina treated surface water, January-December 1971

Month (1971)	Treated water (pCi/liter)									
	Ash-ville	Hickory	Winston-Salem	Roanoke Rapids	Lilling-ton	Smith-field	Char-lotte	Mt, Gilead	Wilm-ington	Green-ville
January	ND	<3.0	ND	7.30	ND	ND	ND	ND	ND	ND
February	<3.0	<3.0	4.00	ND	5.00	ND	3.80	3.10	3.70	6.10
March	<3.0	ND	<3.0	3.80	4.20	5.10	3.50	3.30	5.20	4.80
April	<3.0	<3.0	<3.0	<3.0	3.80	4.20	<3.0	3.50	3.90	3.60
May	<3.0	3.50	23.90	ND	5.50	5.10	3.60	3.50	5.00	5.00
June	<3.0	ND	<3.0	ND	7.40	4.40	<3.0	4.20	4.70	5.60
July	<3.0	<3.0	<3.0	ND	8.10	6.00	<3.0	4.40	4.30	5.20
August	<3.0	<3.0	3.40	3.70	5.50	5.90	<3.0	4.30	3.80	5.10
September	<3.0	ND	<3.0	ND	ND	5.50	<3.0	<3.0	4.20	5.70
October	<3.0	<3.0	<3.0	3.80	4.90	5.10	<3.0	3.70	4.10	4.90
November	<3.0	<3.0	<3.0	ND	4.00	ND	<3.0	3.60	3.90	ND
December	ND	<3.0	ND	ND	3.80	3.70	<3.0	<3.0	3.20	4.00

ND, nondetectable.

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the total gross beta is greater than 5 pCi/liter, a strontium-89 and strontium-90 determination is performed.

A summary of surface water data is provided in table 1 (raw) and table 2 (treated).

Sewage treatment plant effluent water

Samples are taken on a monthly basis at three sewage treatment plants. They routinely are collected by plant personnel in 1-gallon polyethylene containers and mailed to the State laboratory for analysis. Additional samples can be collected if needed. Samples are prepared in the same manner as untreated surface water.

A summary of sewage treatment plant effluent water data is provided in table 3.

Saline water

One gallon of saline water is collected and processed the same as the untreated surface samples. However, because of high solids content, only 200 milliliters is filtered for alpha and beta measurement. The gross alpha and beta radioactivity in saline water for Morehead City for July was <1.0 and 269.0 pCi/liter respectively.

Bottom silt

Bottom sediment was collected in 1-liter samples. The silt is transferred to a 1-liter polyethylene Marinelli beaker for gamma analysis after rocks and other unwanted materials are removed. The sample is then ashed at 560 degrees centigrade for 36 hours, weighed, plancheted, and submitted for gross alpha and beta counting.

The gross alpha and beta radioactivity in bottom silt (Morehead City) for July was <1.0 and 5150 pCi/liter, respectively.

Summary of results

All environmental radioactivity concentrations during 1971 were well below the limits set for protection of the public's health. There were no significant or unexpected differences between these results and the 1968–1970 results.

Detectable quantities of fission products were observed in many samples during the reporting period. Increases in fission product inventories correlated well with reported nuclear detonations.

The continued demonstration of the ability of the network to detect low levels of radioactivity ensures that higher levels which could affect public health will not go unnoticed.

REFERENCE

(*1*) PORTER, C. R., R. J. AUGUSTINE, J. M. MATUSEK, Jr., and M. W. CARTER. Procedures for determination of stable elements and radionuclides in environmental samples, PHS Publication No. 999-RH 10. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (January 1965).

Previous coverage in *Radiation Data and Reports:*

Period	Issue
1968–1970	September 1972

Table 3. Gross alpha and beta radioactivity in sewage treatment effluent water, North Carolina, January-December 1971

1971	Concentration (pCi/liter)					
	Durham		Winston-Salem		Charlotte	
	Gross alpha	Gross beta	Gross alpha	Gross beta	Gross alpha	Gross beta
January	ND	ND	ND	ND	ND	ND
February	<1.0	21.7	<1.0	58.1	ND	14.8
March	<1.0	21.9	<1.0	42.4	<1.0	12.3
April	<1.0	11.0	<1.0	56.3	<1.0	10.9
May	<1.0	10.7	<1.0	49.6	<1.0	9.10
June	<1.0	14.8	<1.0	47.9	<1.0	12.1
July	<1.0	14.9	<1.0	6.20	<1.0	10.9
August	<1.0	28.9	ND	ND	<1.0	12.8
September	<1.0	26.1	<1.0	37.6	<1.0	8.90
October	<1.0	13.1	<1.0	43.6	<1.0	9.20
November	<1.0	7.60	ND	ND	<1.0	12.6
December	<1.0	29.0	<1.0	45.8	ND	ND

ND, nondetectable.

SECTION III. AIR AND DEPOSITION

Radioactivity in Airborne Particulates and Precipitation

Continuous surveillance of radioactivity in air and precipitation provides one of the earliest indications of changes in environmental fission product radioactivity. To date, this surveillance has been confined chiefly to gross beta radioanalysis. Although such data are insufficient to assess total human radiation exposure from fallout, they can be used to determine when to modify monitoring in other phases of the environment.

Surveillance data from a number of programs are published monthly and summarized periodically to show current and long-range trends of atmospheric radioactivity in the Western Hemisphere. These include data from activities of the Environmental Protection Agency, the Canadian Department of National Health and Welfare, and the Pan American Health Organization.

In addition to those programs presented in this issue, the following programs were covered previously in *Radiation Data and Reports.*

Network	Period	Issue
Fallout in the United States and other areas, *HASL*	1971	August 1973
Krypton-85 in air	July 1970–1972	March 1974
Mexican air monitoring	July–December 1973	May 1974
Plutonium in airborne particulates	April–June 1973	June 1974
Surface air sampling program, 80th Meridian Network, *HASL*	1971	September 1973

1. Radiation Alert Network
February 1974

Eastern Environmental Radiation Facility
Environmental Protection Agency

Surveillance of atmospheric radioactivity in the United States is conducted by the Radiation Alert Network (RAN). Samples are collected at 68 locations throughout the country (figure 1). Most of the stations are operated by State health department personnel.

The station operators perform "field estimates" on the airborne particulate samples at 5 hours after collection, when most of the radon daughter products have decayed, and at 29 hours after collection, when most of the thoron daughter products have decayed. The airborne particulate samples and precipitation samples are sent to the Eastern Environmental Radiation Facility for further analysis. All field estimate results are reported to appropriate Environmental Protection Agency officials by mail or telephone depending on levels found. A compilation of the daily measurements is available upon request from the Eastern Environmental Radiation Facility, Montgomery, Ala. 36109. A detailed description of the sampling and analytical procedures was presented in the March 1968 issue of *Radiological Health Data and Reports.*

Table 1 presents the monthly average gross beta radioactivity in surface air particulates and deposition by precipitation, as measured by the field estimate and laboratory techniques during February 1974.

The Office of Radiation Programs is in the process of modifying the air program to make it more responsive to potential sources of environmental radioactivity. These changes will be reflected in future articles.

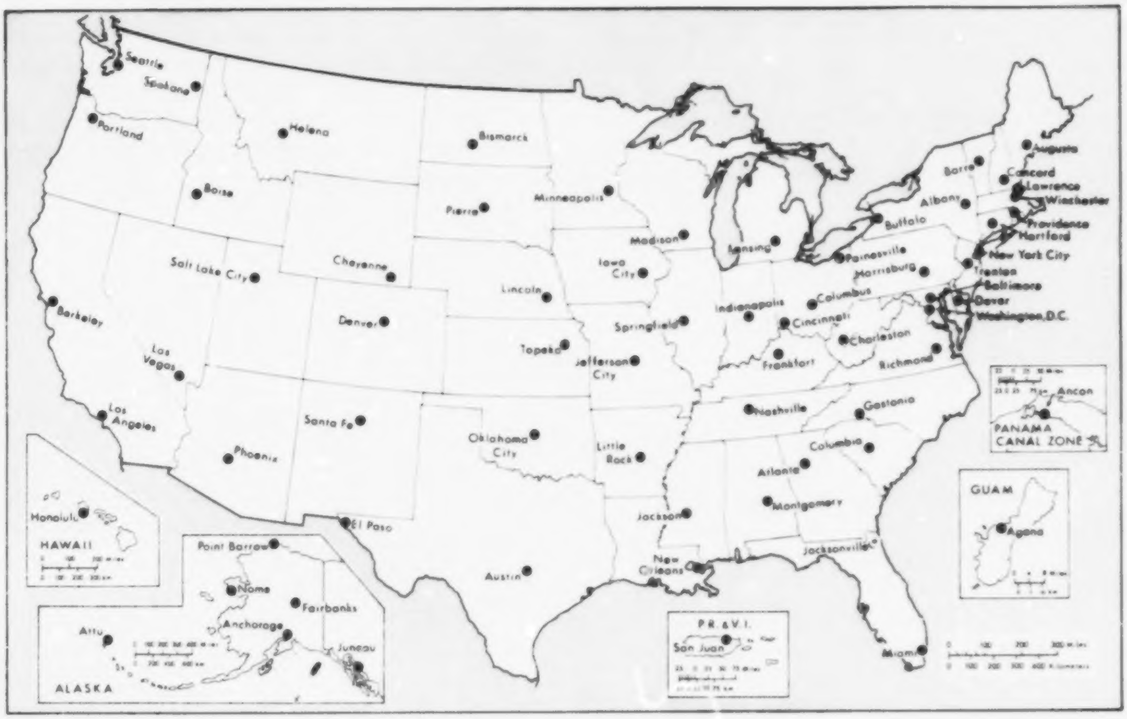
Seattle
Spokane
Portland
Helena
Bismarck
Boise
Pierre
Minneapolis
Salt Lake City
Cheyenne
Lincoln
Madison
Lansing
Iowa City
Berkeley
Denver
Topeka
Springfield
Indianapolis
Columbus
Cincinnati
Charleston
Frankfort
Richmond
Jefferson City
Los Vegas
Los Angeles
Santa Fe
Oklahoma City
Little Rock
Nashville
Gastonia
Phoenix
Atlanta
Columbia
Montgomery
Jackson
El Paso
Austin
New Orleans
Jacksonville
Miami
Augusta
Barre
Concord
Lawrence
Winchester
Albany
Buffalo
Providence
Hartford
Painesville
Harrisburg
New York City
Trenton
Baltimore
Dover
Washington, D.C.
Ancon
PANAMA CANAL ZONE
GUAM
Agana
Honolulu
HAWAII
Point Barrow
Nome
Fairbanks
Anchorage
Attu
Juneau
ALASKA
P.R. & V.I.
San Juan

Figure 1. Radiation Alert Network sampling stations

Table 1. Gross beta radioactivity in surface air and precipitation, February 1974

Station location [a]		Number of samples	Gross beta radioactivity (pCi/m³)						Precipitation	
			5-hour field estimate			Laboratory measurement			Laboratory estimate of deposition	
			Maximum	Minimum	Average [b]	Maximum	Minimum	Average [b]	Depth (mm)	Total deposition (nCi/m²)
Ala:	Montgomery	7	1	0	0	0.16	0.03	0.07	54	0.26
Alaska:	Anchorage	2	0	0	0	.04	.02	.03		
Calif:	Berkeley	8	1	0	0	.07	.03	.05	12	.05
	Los Angeles	8	2	0	1	.13	<.01	.07		
Colo:	Denver	8	1	0	0	.23	.04	.12	4	.05
Idaho:	Idaho Falls	8				.12	.03	.06	18	.12
Ind:	Indianapolis	8	0	0	0	.09	.03	.06		
Nev:	Las Vegas	8	1	0	1	.13	.05	.09	1	.07
N. Mex:	Santa Fe	8	1	0	0	.13	.07	.09		
N.Y:	Buffalo	8	0	0	0	.11	.04	.06	2	.02
N. Dak:	Bismarck	8	2	0	1	.08	.04	.06	8	.12
Ohio:	Columbus	7	0	0	0	.08	.06	.07		
Okla:	Oklahoma City	4	2	1	1	.09	.06	.07		
Oreg:	Portland	18	0	0	0	.05	<.01	.03		
Pa:	Harrisburg	17	1	0	0	.10	.03	.04		
S.C:	Columbia	8	1	0	0	.09	.05	.07	84	.45
Network summary		135	2	0	0	0.23	<0.01	0.07	23	0.14

[a] The remaining stations are on standby status.
[b] The monthly average is calculated by weighting the estimates of individual air samples with length of sampling period.

2. Air Surveillance Network February 1974

National Environmental Research Center—
Las Vegas
Environmental Protection Agency

The Air Surveillance Network,[1] operated by the National Environmental Research Center—Las Vegas (NERC–LV), consists of 49 active and 72 standby sampling stations located in 21 western States (figures 2 and 3). The network is operated in support of nuclear testing sponsored by the U.S. Atomic Energy Commission (AEC) at the Nevada Test Site (NTS), and at any other designated testing sites.

The stations are operated by State health department personnel and by private individuals on a contract basis. All active stations are operated continuously with filters being exchanged after periods generally ranging from 48 to 72 hours. All samples are mailed to the NERC–LV unless special retrieval is arranged at selected locations in response to known releases of radioactivity from the NTS. A complete description of sampling and analytical procedures was presented in the February 1972 issue of *Radiation Data and Reports*.

Table 2 presents the average gross beta concentrations in air for each of the network stations. The minimum reporting concentration for gross beta activity is 0.1 pCi/m³. For reporting purposes, concentrations less than 1.0 pCi/m³ are reported to 1 significant figure, and those equal to or greater than 1.0 pCi/m³ are reported to 2 significant figures. For averaging purposes, individual concentration values less than the minimum detectable concentration (~0.03 pCi/m³ for a 700 m³ sample) are set equal to the minimum detectable concentration (MDC). Reporting and rounding-off conventions are as follows:

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[1] This network is operated under a Memorandum of Understanding (No. AT (26–1)–539) with the Nevada Operations Office, U.S. Atomic Energy Commission.

Concentration (pCi/m^3)	Reported value of concentration above MDC (pCi/m^3)	Reported value of concentration below MDC (pCi/m^3)
<0.05	<0.1	<0.1
≥0.05 <0.15	0.1	<0.1
≥0.15	As calculated and rounded	<calculated MDC

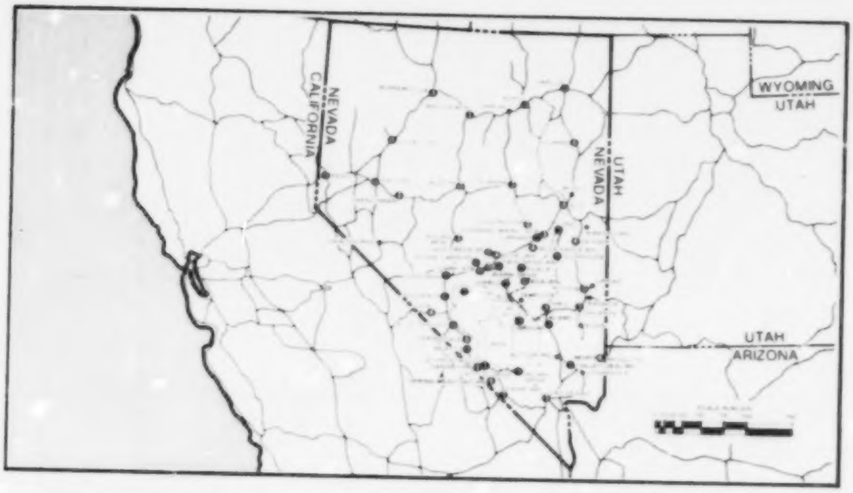
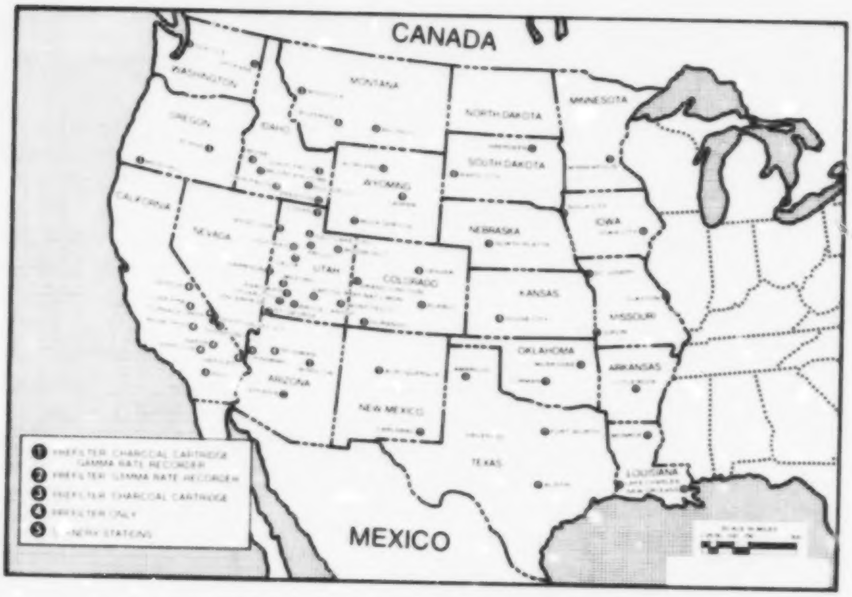

NEVADA
CALIFORNIA
UTAH
NEVADA
WYOMING
UTAH
UTAH
ARIZONA

Figure 2. NERC-LV Air Surveillance Network stations in Nevada


CANADA
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NORTH DAKOTA
MINNESOTA
OREGON
IDAHO
SOUTH DAKOTA
WYOMING
CALIFORNIA
NEVADA
NEBRASKA
IOWA
UTAH
COLORADO
KANSAS
MISSOURI
ARIZONA
NEW MEXICO
OKLAHOMA
ARKANSAS
TEXAS
LOUISIANA
MEXICO
① PREFILTER, CHARCOAL CARTRIDGE GAMMA RATE RECORDER
② PREFILTER, GAMMA RATE RECORDER
③ PREFILTER, CHARCOAL CARTRIDGE
④ PREFILTER ONLY
⑤ NERC STATIONS

Figure 3. NERC-LV Air Surveillance Network stations outside Nevada

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As shown by table 2, the highest gross beta concentration within the network was 1.1 pCi/m^3 at Geyser Ranch, Nev.

From gamma spectrometry results, fission products in varying combinations of zirconium-95, ruthenium-103 and cerium-141 were identified on filters collected in Nevada. The highest concentrations of these radionuclides, respectively, were 0.11 pCi/m^3 (Blue Jay), 0.051 pCi/m^3 (Groom Lake), and 0.035 pCi/m^3 (Blue Jay). These radionuclides are attributed to annual worldwide fallout. No radionuclides were identified by gamma spectrometry on any charcoal cartridges during February.

Complete copies of this summary and listings of the daily gross beta and gamma spectrometry results are distributed to EPA Regional Offices and appropriate State agencies. Additional copies of the daily results may be obtained from the NERC/LV upon written request.

Table 2. Summary of gross beta radioactivity concentrations in air, February 1974

Location		Number of samples	Concentration (pCi/m^3)		
			Maximum	Minimum	Average [a]
Ariz:	Kingman	12	0.4	<0.1	0.2
	Seligman	12	.3	<.1	.2
Calif:	Baker	10	.4	<.1	.2
	Barstow	12	.2	<.1	.1
	Bishop	12	.5	<.1	.3
	Death Valley Junction	12	.3	<.1	.2
	Furnace Creek	12	.2	<.1	.2
	Lone Pine	6	.3	.1	.2
	Needles	3	.2	.1	.2
	Ridgecrest	12	.2	.1	.2
	Shoshone	12	.3	<.1	.2
Nev:	Alamo	12	.3	.1	.2
	Austin	12	.3	<.1	.1
	Beatty	12	.2	<.1	.1
	Blue Eagle Ranch (Currant)	12	.3	<.1	.1
	Blue Jay	12	.4	<.1	.2
	Caliente	12	.2	<.1	.1
	Currant Ranch	12	.3	<.1	.1
	Diablo	12	.3	.1	.2
	Duckwater	12	.2	<.1	.1
	Ely	12	.2	<.1	.1
	Eureka	12	.3	<.1	.1
	Fallini's Twin Springs Ranch	12	.3	<.1	.2
	Geyser Ranch (Pioche)	7	1.1	.1	.2
	Goldfield	12	.2	<.1	.1
	Groom Lake	9	.3	<.1	.2
	Hiko	12	.3	<.1	.2
	Indian Springs	12	.4	.1	.1
	Las Vegas	17	.3	<.1	.2
	Lathrop Wells	12	.3	<.1	.1
	Lida	12	.3	<.1	.1
	Lund	12	.3	<.1	.1
	Mesquite	12	.3	<.1	.1
	Nyala	12	.2	<.1	.1
	Pahrump	13	.3	<.1	.2
	Pioche	12	.2	<.1	.1
	Round Mountain	12	.2	<.1	.1
	Scotty's Junction	12	.3	<.1	.2
	Stone Cabin Ranch	12	.2	.1	.2
	Sunnyside	12	.2	.1	.1
	Tonopah	12	.2	<.1	.1
	Tonopah Test Range	10	.2	<.1	.1
	Warm Springs	11	.3	<.1	.1
	Warm Springs Ranch	12	.3	<.1	.1
Utah:	Cedar City	5	.2	<.1	.1
	Delta	12	.2	.1	.1
	Garrison	12	.3	<.1	.1
	Milford	8	.2	<.1	.1
	St. George	12	.3	<.1	.2

[a] Individual values less than the minimum detectable concentration (MDC) are set equal to the MDC for averaging. A monthly average less than the minimum reportable value of 0.1 pCi/m^3 is reported a <0.1.

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3. Canadian Air and Precipitation Monitoring Program,[2] February 1974

Radiation Protection Bureau
Department of National Health and Welfare

The Radiation Protection Bureau of the Canadian Department of National Health and Welfare monitors surface air and precipitation in connection with its Radioactive Fallout Study Program. Twenty-four collection stations are located at airports (figure 4), where the sampling equipment is operated by personnel from the Atmospheric Environment Service of the Department of the Environment. Detailed discussions of the sampling procedures, methods of analysis, and interpretation of results of the radioactive fallout program are contained in reports of the Department of National Health and Welfare (*1–5*).

A summary of the sampling procedures and methods of analysis was presented in the May 1969 issue of *Radiological Health Data and Reports*.

Surface air and precipitation data for February 1974 are presented in table 3.

Table 3. Canadian gross beta radioactivity in surface air and precipitation, February 1974

Location	Number of samples	Air surveillance gross beta radioactivity (pCi/m³)			Precipitation	
		Maximum	Minimum	Average	Average concentration (pCi/liter)	Total deposition (nCi/m²)
Calgary	4	0.08	0.01	0.05	20.3	0.4
Coral Harbour	4	.06	.04	.05	25.1	.2
Edmonton	4	.07	.05	.06	13.9	.5
Ft. Churchill	4	.07	.03	.05	38.2	.2
Fredericton	3	.05	.04	.05	22.1	1.6
Goose Bay	4	.04	.02	.03	5.7	.4
Halifax	4	.07	.04	.06	13.7	2.4
Inuvik	2	.03	.01	.02	NS	NS
Montreal	4	.03	.01	.02	17.9	.7
Moosonee	4	.06	.04	.05	NS	NS
Ottawa	4	.04	.01	.03	25.0	1.1
Quebec	4	.04	.03	.04	NS	NS
Regina	3	.07	.06	.07	10.0	.3
Resolute	4	.06	.04	.05	115.0	.4
St John's, Nfld.	4	.02	.01	.02	38.5	2.8
Saskatoon	4	.06	.04	.05	30.8	.3
Sault Ste. Marie	4	.05	.04	.05	17.6	.6
Thunder Bay	4	.05	.03	.04	NS	NS
Toronto	NS				29.4	1.6
Vancouver	4	.03	.02	.03	11.2	1.2
Whitehorse	4	.06	.02	.04	38.7	.5
Windsor	NS				23.4	1.7
Winnipeg	4	.07	.03	.05	NS	NS
Yellowknife	NS				38.8	.3
Network summary	80	0.08	0.01	0.04	28.2	0.9

NS, no sample

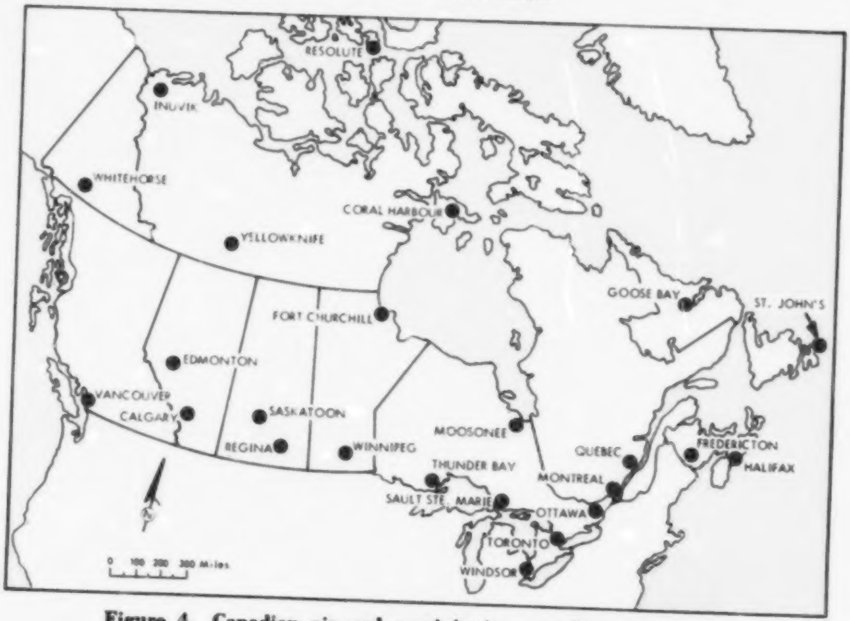
RESOLUTE
INUVIK
WHITEHORSE
CORAL HARBOUR
YELLOWKNIFE
GOOSE BAY
ST. JOHN'S
FORT CHURCHILL
EDMONTON
VANCOUVER
CALGARY
SASKATOON
REGINA
WINNIPEG
MOOSONEE
QUEBEC
FREDERICTON
HALIFAX
THUNDER BAY
MONTREAL
SAULT STE. MARIE
OTTAWA
TORONTO
WINDSOR
0 100 200 300 Miles

Figure 4. Canadian air and precipitation sampling stations

74

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[2] Prepared from information and data obtained from the Canadian Department of National Health and Welfare, Ottawa, Canada.

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(1) BIRD, P. M., A. H. BOOTH, and P. G. MAR. Annual report of 1959 on the Radioactive Fallout Study Program, CNHW–RP–3. Department of National Health and Welfare, Ottawa, Canada (May 1960).

(2) BIRD, P. M., A. H. BOOTH, and P. G. MAR. Annual report for 1960 on the Radioactive Fallout Study Program, CNHW–RP–4. Department of National Health and Welfare, Ottawa, Canada (December 1961).

(3) MAR, P. G. Annual report for 1961 on the Radioactive Fallout Study Program, CNHW–RP–5. Department of National Health and Welfare, Ottawa, Canada (December 1962).

(4) BEALE, J. and J. GORDON. The operation of the Radiation Protection Division Air Monitoring Program, RPD–11. Department of National Health and Welfare, Ottawa, Canada (July 1962).

(5) BOOTH, A. H. The calculation of permissible levels of fallout in air and water and their use in assessing the significance of 1961 levels in Canada, RPD–21. Department of National Health and Welfare, Ottawa, Canada (August 1962).

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4. Pan American Air Sampling Program February 1974

Pan American Health Organization and U.S. Environmental Protection Agency

Gross beta radioactivity in air is monitored by countries in the Americas under the auspices of the collaborative program developed by the Pan American Health Organization (PAHO) and the Environmental Protection Agency (EPA) to assist PAHO-member countries in developing radiological health programs.

The air sampling station locations are shown in figure 5. Analytical techniques were described in the March 1968 issue of *Radiological Health Data and Reports*. The February 1974 air monitoring results from the participating countries are given in table 4.

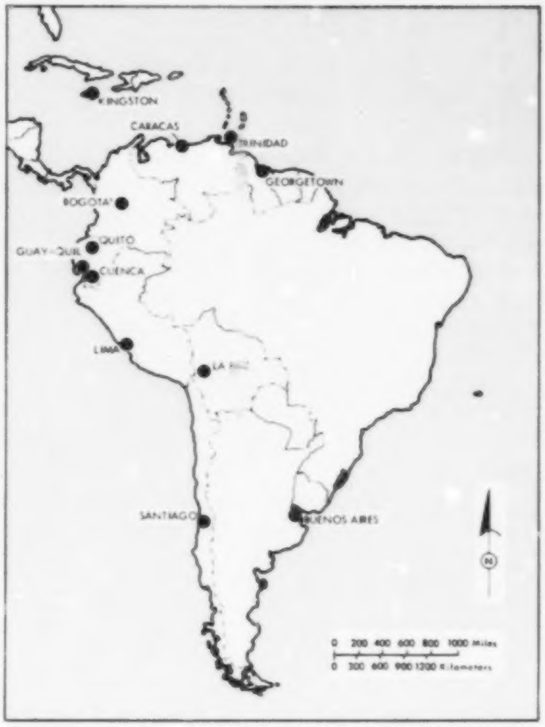

Figure 5. Pan American Air Sampling Program stations

Table 4. Summary of gross beta radioactivity in Pan American surface air, February 1974

Station location		Number of samples	Gross beta radioactivity (pCi/m^3)		
			Maximum	Minimum	Average [a]
Argentina:	Buenos Aires	0			
Bolivia:	La Paz	0			
Chile:	Santiago	0			
Colombia:	Bogota	19	0.07	0.00	0.03
Ecuador:	Cuenca	2	.01	.00	.01
	Guayaquil	16	.04	.00	.02
	Quito	12	.02	.00	.00
Guyana:	Georgetown	0			
Jamaica:	Kingston	0			
Peru:	Lima	15	.03	.00	.01
Trinidad and Tobago:	Port of Spain	0			
Venezuela:	Caracas	13	.06	.00	.03
Pan American summary		77	0.07	0.00	0.02

[a] The monthly average is calculated by weighting the individual samples with length of sampling period. Values less than 0.005 pCi/m^3 are reported and used in averaging as 0.00 pCi/m^3

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5. California Air Sampling Program February 1974

Radiologic Health Section
California Department of Health

The Radiologic Health Section of the California Department of Health with the assistance of several cooperating agencies and organizations operates a surveillance system for determining radioactivity in airborne particulates. The air sampling locations are shown in figure 6.

One of the objectives of the program is to evaluate the possibility that fixed effluent sources contribute to particulate activity in the air. Consequently, data from continuous air samplers placed in proximity to nuclear facilities are compared with those from similar equipment in nearby communities and at several "background" stations.[1]

Airborne particles are collected by a continuous sampling of air filtered through a 47

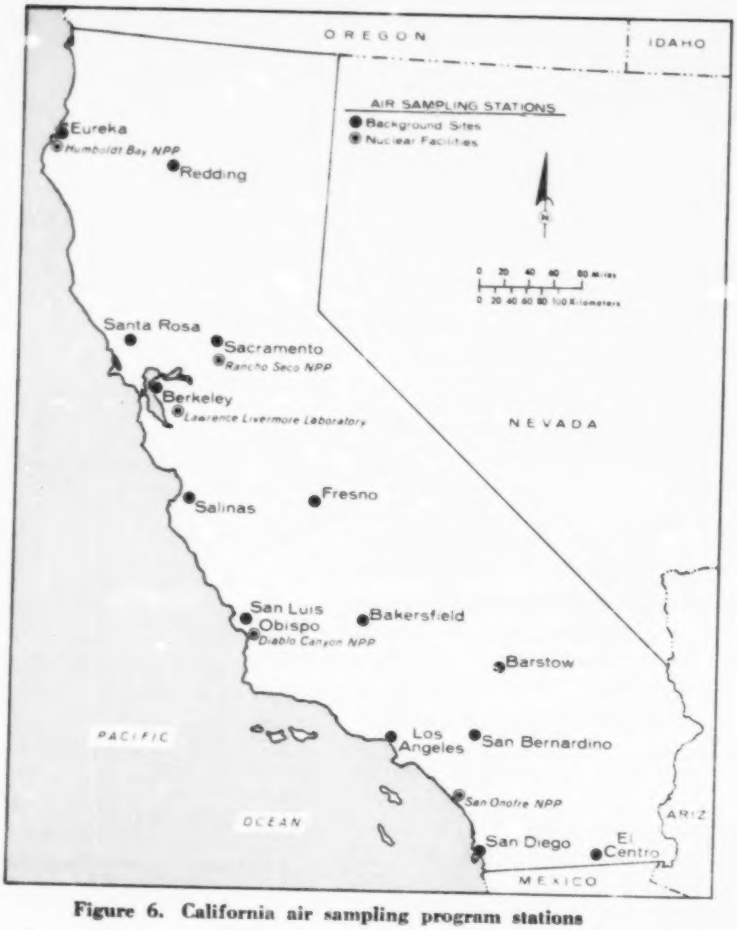
OREGON
IDAHO
AIR SAMPLING STATIONS
● Background Sites
● Nuclear Facilities
0 20 40 60 80 Miles
0 20 40 60 80 100 Kilometers
Eureka
Humboldt Bay NPP
Redding
Santa Rosa
Sacramento
Rancho Seco NPP
Berkeley
Lawrence Livermore Laboratory
NEVADA
Salinas
Fresno
San Luis Obispo
Diablo Canyon NPP
Bakersfield
Barstow
PACIFIC
OCEAN
Los Angeles
San Bernardino
San Onofre NPP
San Diego
El Centro
ARIZ
MEXICO

Figure 6. California air sampling program stations

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[1] Air samples near nuclear power reactors were obtained under contract number AT(49-1)-3549 between the U.S. Atomic Energy Commission and the California Department of Health.

millimeter membrane filter, 0.8 micron pore size, using a Gast air pump of about 2 cubic feet per minute capacity, or 81.5 cubic meters per day. Air volumes are measured with a direct reading gas meter. Filters are replaced every 24 hours except on holidays and weekends.

All air samples are sent to the Sanitation and Radiation Laboratory of the State Department of Health. The filters are analyzed for gross alpha and beta radioactivity, 72 hours after the end of the collection period. The daily samples then are composited into a monthly sample for gamma spectroscopy and an analysis for strontium-89 and strontium-90. The monthly sample results are presented quarterly. Table 5 presents the gross beta radioactivity in air for February 1974.

Table 5. Gross beta radioactivity in California air February 1974

Station location	Number of samples	Gross beta radioactivity (pCi/m³)		
		Maximum	Minimum	Average
Bakersfield	18	0.85	0.07	0.30
Barstow	28	.50	.10	.28
Berkeley	28	.32	.02	.15
Diablo Canyon Nuclear Power Plant	8	.24	.10	.19
El Centro	18	1.31	.00	.29
Eureka	18	.26	.06	.11
Fresno	17	.52	.09	.22
Humboldt Bay Power Plant: Unit 3	12	.12	.03	.08
Los Angeles	18	.40	.10	.23
Rancho Seco Nuclear Generating Station	12	.23	.00	.17
Redding	14	.35	.10	.20
Sacramento	19	.28	.00	.11
Salinas	18	.54	.05	.23
San Bernardino	13	.45	.12	.30
San Diego	17	.53	.13	.24
San Luis Obispo	18	.41	.03	.21
San Onofro Nuclear Generating Station	4	.30	.17	.25
Santa Rosa	3	.12	.04	.09
Summary	283	1.31	0.00	0.20

SECTION IV. OTHER DATA

This section presents results from routine sampling of biological materials and other media not reported in the previous sections. Included here are such data as those obtained from human bone sampling, Alaskan surveillance, and environmental monitoring around nuclear facilities.

Environmental Levels of Radioactivity at Atomic Energy Commission Installations

The U.S. Atomic Energy Commission (AEC) receives from its contractors annual reports on the environmental levels of radioactivity in the vicinity of major Commission installations. The reports include data from routine monitoring programs where operations are of such a nature that plant environmental surveys are required.

Releases of radioactive materials from AEC installations are governed by radiation standards set forth by AEC's Division of Operational Safety in directives published in the "AEC Manual."[1]

A summary of the environmental radioactivity data follow for Brookhaven National Laboratory and Oak Ridge Area.

1. Brookhaven National Laboratory[2]
January–December 1971

Associated Universities, Inc.
Upton, N.Y.

Brookhaven National Laboratory is a scientific research center situated in Suffolk County on Long Island, about 70 miles east of New York City. Its location with regard to surrounding communities is shown in figure 1. Except for shoreline communities, much of the land area within 10 miles is currently either forested or under cultivation.

The laboratory site with its principal effluent-producing facilities is shown in figure 2. It consists of some 4500 acres, most of which is wooded, except for a central area of less than 1000 acres. The site terrain is gently rolling, with elevations varying 40 and 120 feet above

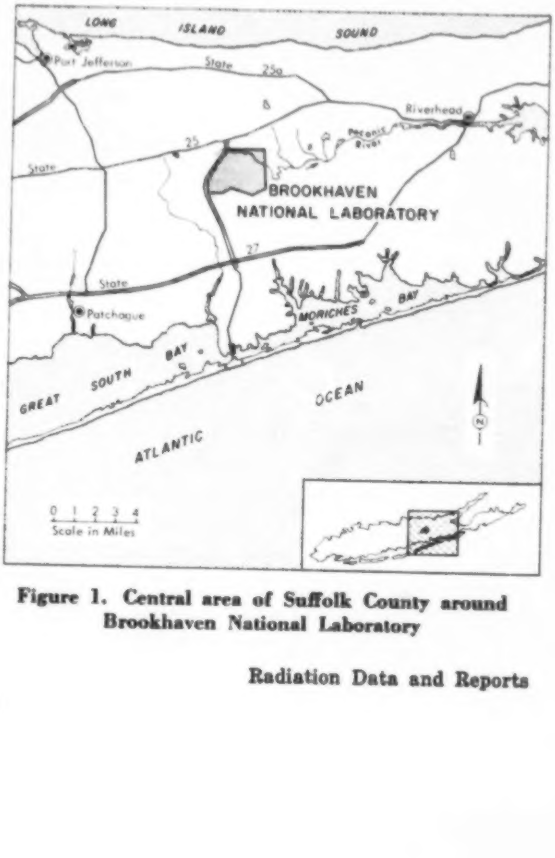

Figure 1. Central area of Suffolk County around Brookhaven National Laboratory

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[1] Title 10, Code to Federal Regulations, Part 20, "Standards for Protection Against Radiation" contains essentially the standards published in Chapter 0524 of the AEC Manual.

[2] Summarized from "Brookhaven National Laboratory, 1971 Environmental Monitoring Report, 1971," Associated Universities Inc., Upton, N.Y. 11973.

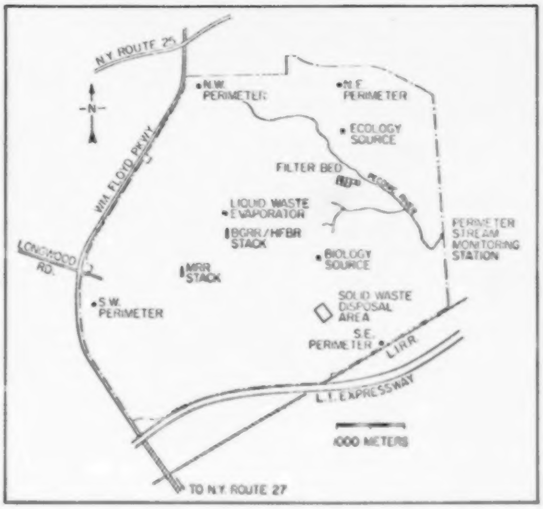

Figure 2. Effluent producing facilities, Brookhaven National Laboratory

sea level. The land lies on the west rim of the shallow Peconic River watershed, with the river itself rising in marshy areas in the north and east sections of the site.

A wide variety of scientific programs are conducted at Brookhaven, including research or development in the following areas:

1) structure and properties of matter;

2) physical, chemical and biological effects of radiation;

3) radioisotopes and other nuclear tools, and;

4) nuclear technology.

Among the major scientific facilities operated at Brookhaven to carry out the above programs are: the High Flux Beam Reactor (HFBR) is enriched uranium fueled, heavy water moderated and cooled, and has a routine power level of 40 MW; the Medical Research Reactor (MRR) is an integral part of the Medical Research Center, is enriched uranium fueled, natural water moderated and cooled, and is operated intermittently at power levels up to 3 MW; the Alternating Gradient Synchrotron (AGS) operates at energies up to 33 BeV; the 200 MeV Proton Linac serves as an injector for the AGS, but will also supply continuous currents of protons for isotope production by spallation reactions; the Tandem Van de Graaff, 60-inch Cyclotron, Research Van de Graaff, Vertical Accelerator and Chemistry Van de Graaff are used in medium energy investigation, as well as for special isotope production, and; the High Intensity Radiation Development Laboratory (HIRDL) contains million-curie range cobalt-60 and cesium-137 sources.

Additional programs involving irradiations and/or the use of radionuclides for scientific investigations are carried on at other laboratory facilities, including the Medical Research Center, the Biology Department (including two multicurie field irradiation sources), the Chemistry Department, and the Department of Applied Science. The latter includes the Hot Laboratory, where special purpose radioisotopes are developed and processed for on and offsite use.

Most of the airborne radioactive effluents at Brookhaven originate from the HFBR, the MRR, and the Research Van de Graaff. The first two also produce significant fractions of the laboratory's liquid radioactive effluents, but additional significant contributions originate from the Medical Research Center, the Hot Laboratory complex, as well as from decontamination and hot laundry operations.

External exposure monitoring

External radiation levels, including natural background (as influenced by fallout) and increments attributable to BNL activities were measured continuously at the four perimeter stations shown on figure 2. Included in each station's equipment was an ion chamber and dynamic condensor electrometer. Those units are capable of accurately measuring 10 μR/h and of detecting changes of the order of 1 μR/h.

The observed monthly average radiation levels are set forth in table 1. There was no increment to the natural background attributable to BNL activities, except at the northeast perimeter station. At this location, the Ecology Forest irradiation source, which contained about 7000 curies of cesium-137, produced a measurable radiation level. Since the station was located about 250 feet south of the present BNL north boundary, the observed readings have been adjusted on the basis of spot com-

Table 1. External radioactivity at BNL site perimeter including natural background January-December 1971

Month	Average exposure rates (mR/week) [a]					
	Northwest perimeter (background)	Southwest perimeter (background)	Southeast perimeter (background)	Northeast perimeter		All stations (background)
				(background)	(source)	
January	1.74	1.81	1.72	1.68	0.24	1.73
February	1.62	1.65	1.64	1.53	.25	1.64
March	1.64	1.67	1.67	1.59	.26	1.64
April	1.66	1.62	1.62	1.60	.26	1.63
May	1.74	1.73	1.83	1.61	.31	1.73
June	1.76	1.77	1.86	1.59	.32	1.74
July	1.77	1.79	1.85	1.63	.35	1.76
August	1.73	1.92	1.90	1.76	.38	1.83
September	1.72	1.90	1.90	1.72	.37	1.81
October	1.75	1.92	1.98	1.76	.35	1.85
November	1.80	1.97	2.06	1.82	.30	1.91
December	1.78	1.92	2.05	1.79	.28	1.89
Average	1.73	1.81	1.84	1.68	0.31	1.76
Yearly total	90	94	95	87	[b] 16	92
Radiation protection standards (*1*)	—	—	—	—	500	—

[a] Estimated error ±0.10 mR/wk.

[b] Measured 250 feet from north perimeter and adjusted on the basis of spot comparisons between levels at this location and the perimeter.

parisons, which indicate an average ratio of 0.2 between the station and the actual north perimeter radiation levels.

Ground-level air particulate, tritium, and radioiodine

During 1971, "high volume" (20 cubic feet per minute) positive displacement air pumps (Gast 3040) were operated at a monitoring station immediately east of the solid waste disposal area, and at the southeast and southwest perimeter monitoring stations (figure 2). The air sampling media consisted of a 3-inch diameter air particulate filter (Gelman Type G) followed by a 3 inch × 1 inch bed of petroleum-based charcoal (Columbia Grade LC 12/28 × mesh) for sampling of radiohalogens. The solid waste disposal area air particulate filter was changed and counted on a daily (5 times per week) basis. The remaining samples were changed and counted on a 2-week basis through September, and weekly thereafter.

After allowing several days for the decay of short-lived natural radioactivity, gross alpha counts of the 1-day air particulate samples (from the solid waste disposal area stations) were made using a 5-inch diameter ZnS coated photomultiplier. After a similar delay, gross beta counts were made of all air particulate samples, using a 5-inch beta scintillator. These data are shown in table 2. No consistent differences between sampling locations were apparent and there was no indication of BNL effluent radionuclides in air particulate samples at any location.

Continuous tritium vapor collections, using thermoelectric coolers, were made at the southeast and northeast perimeter stations which are most frequently downwind from the high flux beam reactor stack. These collections were composited on a monthly basis, and after enrichment by electrolysis, were assayed for tritium. Net concentrations of tritium vapor in air at the BNL perimeter, which are assumed to be principally attributable to HFBR stack effluent tritium vapor, were arrived at by subtracting the tritium concentrations in an offsite precipitation collection from the concentration found in the perimeter sample. The result was converted to an air concentration by assuming that 1 pCi/ml in vapor corresponds on the average to 10 pCi/cm^3 in air. This is only strictly so at

Table 2. Gross alpha and beta radioactivity in air particulate filters, BNL, January-December 1971

Month	Location	Number of samples	Concentration (fCi/m³)						
			Gross alpha			Number of samples	Gross beta		
			Maximum	Minimum	Average		Maximum	Minimum	Average
January	Waste disposal	15	2.9	0.5	0.7	21	116	45	75
	SW perimeter	—				2	112	80	96
	SE perimeter	—				—	—	—	—
February	Waste disposal	15	2.1	<1	1.2	20	153	21	87
	SW perimeter	—				2	102	59	81
	SE perimeter	—				2	142	83	112
March	Waste disposal	19	1.9	1	1.1	23	338	58	177
	SW perimeter	—				2	164	140	152
	SE perimeter	—				2	199	143	171
April	Waste disposal	17	2.2	<1	.9	22	395	43	230
	SW perimeter	—				2	214	212	213
	SE perimeter	—				2	255	255	255
May	Waste disposal	14	7.0	1	1.4	24	910	72	428
	SW perimeter	—				2	445	258	352
	SE perimeter	—				2	450	128	289
June	Waste disposal	17	3.3	1	1.2	22	760	82	458
	SW perimeter	—				2	406	386	396
	SE perimeter	—				2	472	393	432
July	Waste disposal	15	1.8	1	.9	23	660	128	420
	SW perimeter	—				2	461	281	371
	SE perimeter	—				2	544	342	443
August	Waste disposal	18	3.2	<1	1.1	23	905	74	263
	SW perimeter	—				2	245	222	234
	SE perimeter	—				2	287	239	263
September	Waste disposal	17	1.6	1	.8	23	195	68	118
	SW perimeter	—				3	143	80	123
	SE perimeter	—				3	148	72	120
October	Waste disposal	16	3.1	<1	.8	23	144	24	77
	SW perimeter	—				4	171	27	93
	SE perimeter	—				4	182	48	104
November	Waste disposal	21	2.1	4	.9	21	165	38	80
	SW perimeter	—				4	67	46	57
	SE perimeter	—				4	90	72	84
December	Waste disposal	22	1.8	5	.8	22	128	27	74
	SW perimeter	—				4	86	43	43
	SE perimeter	—				4	96	76	86
1971 summary	Waste disposal	206	7.0	<1	1.0	267	910	21	207
	SW perimeter	—				33	461	27	179
	SE perimeter	—				31	544	48	215
Estimated error (at 95 percent confidence level)			±0.1 fCi m³ or ±25 percent				±10 percent		
Radiation protection standard (1)			[a] 100				[b] 10 000		

[a] For unidentified alpha emitters.
[b] For unidentified beta emitters.

59°F and 50 percent relative humidity. These air concentration data are shown in table 3.

In addition to the gross beta counts indicated above, analyses for gamma-emitting nuclides were performed on a consolidated monthly composite of all individual air particulate samples shortly after the end of each month. Additional air particulate analyses were also scheduled at 6-month and 1-year postcollection to facilitate the resolution of short- and long-lived nuclides with photopeaks too close to be resolved by the NaI detection system employed. The charcoal samples were reanalyzed at 1-month postcollection to determine iodine-131 by decay in its photopeak region during this time. Available data are reported in table 4. In the absence of any recent fission products during most of the year, all transactions in the energy region of iodine-131 have been attributed to 285-day cerium-144. These data do not disclose any indication of BNL effluents.

Precipitation

Two pot-type rain collectors, each with a surface area of 0.33 m², were situated adjacent to the BNL filter beds. Two routine collections were made from these, one whenever precipitation was observed during a previous 24-hour (or weekend) period, and the other, once a week whether or not precipitation had occurred.

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Table 3. Tritium concentrations in air, BNL January-December 1971

Month	Number of samples	Southwest perimeter Concentration (pCi/m³)	Number of samples	Northeast perimeter Concentration (pCi/m³)
January	[a] 1	11	0	—
February	[a] 1	10	0	—
March	[a] 1	5	0	—
April	[a] 1	4	[a] 1	10
May	[a] 1	3	[a] 1	9
June	[a] 1	15	[a] 1	12
July	[a] 1	0	[a] 1	15
August	[a] 1	1	[a] 1	3
September	[a] 1	0	[a] 1	4
October	[a] 1	2	[a] 1	3
November	0	—	0	—
December	[a] 1	3	0	—
Average		5		8
Radiation protection standard (1)		200 000		200 000

[a] Tritium analysis made of monthly composite samples of water vapor. The net tritium concentration in this, arrived at by subtracting that in an offsite precipitation sample, is converted to air concentration on the assumption that on the average 1 pCi/m in vapor corresponds to 10 pCi/m³ in air which is strictly so at 59°F. and 50 percent relative humidity.

Estimated error (at 95-percent confidence limits): ±1 pCi/m³, or ±50 percent.

Part of each collection was evaporated for gross beta counting, a small fraction composited for monthly tritium analysis, and the balance put through ion exchange columns for subsequent monthly strontium-89, strontium-90 and gamma analyses. The data are reported in table 5.

With the exception of tritium, there is no indication in the onsite precipitation collection of the washout of BNL released airborne radioactivity. As indicated in table 6, the tritium concentration in the collector located at the filter beds (which are in a predominant downwind direction) appears to have been about twice that of the offsite collection. The total deposition of tritium on the BNL site (about 4000 acres) during 1971 was between 5–10 curies. The lower estimate is based on the concentration in the offsite collection, and the upper on that in the onsite downwind sample.

Liquid effluent monitoring

Within established administrative limits, microcurie amounts of low-level radioactive liquid effluents are routinely disposed of by release into the laboratory's sanitary waste system. This affords considerable dilution by a large volume (~10^6 gal/day) of uncontaminated water. Primary treatment to remove suspended solids from the liquid effluents discharged to this system is provided by a 250 000 gallon clarifier. The liquid effluent then flows onto sand filter beds, from which most of it is recovered by an underlying tile field. It is then

Table 4. Gamma-emitting radionuclides in monthly air composites, BNL, January-December 1971

Month	Radionuclide concentration (fCi/m³)								
	Beryllium-7	Zinc-65	Zirconium-niobium 95	Ruthenium-106	Antimony-125	Iodine-131 [a]	Cesium-137	Barium-lanthanum-140	Cerium-144
January	94	1	12	7	1	<1	4	<1	22
February	103	3	19	7	3	<1	5	<1	28
March	243	3	70	18	3	<1	10	<1	77
April	374	3	142	13	4	<1	12	<1	118
May	476	7	227	43	7	<1	17	<1	188
June	498	10	274	51	8	<1	26	<1	235
July	435	9	192	39	8	<1	23	<1	202
August	222	7	104	33	5	1	17	<1	111
September	167	3	42	14	3	<1	17	<1	54
October	84	2	13	6	2	<1	3	<1	25
November	77	1	9	5	1	1	3	4	21
December	96	1	5	4	1	2	2	3	16
Average	231	4	[c] 24	20	3	<1	12	<1	91
Estimated percent error of individual sample	±25	±50	±25	±33	±33	±50	±25	±50	±25
Radiation protection standard	4×10^7	2×10^6	1×10^6	2×10^5	9×10^5	1×10^5	5×10^5	1×10^6	2×10^5

[a] Charcoal filter collection; all other nuclides collected on air particulate filter.

[b] Pending.

Table 5. Gross beta and radionuclide activity in precipitation, BNL January-December 1971

Month	Amount (inches)	Gross beta concentration (pCi/liter)	Gross beta deposition (nCi/m²)	Radionuclide deposition (nCi/m²)							
				^{7}Be	^{65}Zn	^{90}Sr	^{95}Zr-Nb	^{131}I	^{137}Cs	^{140}Ba-La	^{144}Ce
January	1.97	31	1.57	5.2	<0.1	0.04	0.4	0.1	0.1	0.1	1.8
February	4.62	42	2.34	14.4	<.1	.12	2.7	<.1	.2	<.1	1.2
March	2.37	81	4.95	9.6	<.1	.17	3.5	<.1	.2	<.1	1.4
April	1.70	122	4.59	4.6	<.1	.05	1.2	<.1	.2	<.1	1.3
May	3.12	169	14.03	26.6	.1	.30	7.6	<.1	1.0	<.1	3.0
June	.74	219	4.39	10.3	<.1	.27	3.4	<.1	.5	<.1	1.8
July	3.37	36	2.72								
August	5.57	19	2.53	6.7	<.1	.13	1.1	<.1	.2	<.1	1.5
September	1.98	9	.38	1.4	<.1	.05	.2	<.1	.1	<.1	.8
October	3.11	16	1.25	5.9	<.1	.14	.4	<.1	.1	<.1	1.2
November	3.45	39	4.75	1.7	<.1	.11	.1	<.1	<.1	<.1	.8
December	3.23	58	4.77	4.8	.1	.05	.4	.3	.1	.6	.6
Summary	35.23	[a] 56	48.27	91.2	<1.0	1.43	21.0	<1.0	2.8	<1.0	15.5
Average estimated error	0.25	±6	±2.39	±19.0	—	±0.14	±2.1	—	±0.8	—	±3.8
Radiation protection standard (*1*) [a]		3×10³									

[a] For release to uncontrolled areas of mixture of radionuclides containing <10 percent strontium-90, iodine 125-133, and long-lived natural alpha-emitting nuclides.

Table 6. Average tritium concentration in precipitation BNL, January-December 1971

Month	Onsite		Offsite
	Concentration (pCi/liter)	Deposition (nCi/m³)	Concentration (pCi/liter)
January	661	33	300
February	300	17	210
March	1 570	96	459
April	1 470	55	605
May	972	81	705
June	1 186	136	523
July			
August	460	61	306
September	325	41	82
October			
November	273	16	104
December	248	20	148
Total	[a] 650	556	[a] 320
Average estimated error	±65	±57	±32
Radiation protection standard (*1*)[b]	3×10⁶		3×10⁶

[a] Weighted average.
[b] For tritium in water released to the offsite environment.

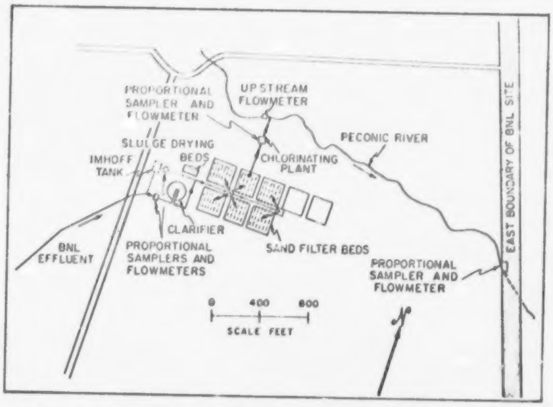
PROPORTIONAL SAMPLER AND FLOWMETER
UPSTREAM FLOWMETER
PECONIC RIVER
SLUDGE DRYING BEDS
IMHOFF TANK
CHLORINATING PLANT
EAST BOUNDARY OF BNL SITE
CLARIFIER
BNL EFFLUENT
PROPORTIONAL SAMPLERS AND FLOWMETERS
SAND FILTER BEDS
PROPORTIONAL SAMPLER AND FLOWMETER
0
400
800
SCALE FEET
N

Figure 3. Sewage treatment plant, including related monitoring arrangements, Brookhaven National Laboratory

chlorinated and released into a small stream that forms one of the headwaters of the Peconic River.

A schematic illustration of the sewage treatment plant, including the related monitoring arrangements, are shown in figure 3. In addition to the inplant flow measurement and sampling instrumentation, totalizing flowmeters (Leopold and Stevens, TF 61-2), which include provision for actuating a sampler with each 2000 gallons of flow in combination with a positive-action, battery-operated sampler (Brailsford DU-1), are installed at the Chlorine House, at the former site boundary, 0.5 miles downstream on the Peconic and at the site boundary (1.6 miles downstream).

The monthly average flow and the monthly totals of gross beta and principal nuclide activities at the clarifier (input to the filter beds) and at the Chlorine House (output from the beds) are shown in table 7. Yearly totals and average concentrations are also indicated. It is

Table 7. Environmental monitoring liquid effluent flow, total activity and concentration of principal beta and gamma emitters at Clarifier and Chlorine House, BNL, January–December 1971

Month	Flow ($\times 10^8$ liters)	Gross beta[a]	^{3}H	^{7}Be	^{60}Co	^{65}Zn	^{90}Sr	^{95}Zr-Nb	^{131}I	^{137}Cs	^{144}Ce
		Clarifier (mCi)									
January	1.142	1.62	1122	<0.10	0.13	0.07	0.19	<0.01	0.18	0.40	0.34
February	.919	3.05	588	.40	.14	<.01	.15	<.01	2.04	.35	.30
March	.933	1.35	489	.24	.07	<.01	.12	.02	1.01	.19	.30
April	.924	2.54	532	.22	.09	.05	.12	.04	1.62	.26	.57
May	1.477	3.24	1333	<.10	.11	<.01	.27	.62	.72	.66	.40
June	1.209	1.60	4291	.26	.05	<.01	.21	.04	.87	.22	.26
July	1.304	2.51	626	.51	.09	<.01	.20	<.10	.58	.30	.40
August	1.701	13.48	704	<.10	.26	<.01	6.36	<.10	2.63	5.11	1.72
September	1.339	5.77	407	.56	.09	<.01	2.77	<.10	1.17	1.15	.64
October	1.627	3.34	564	.29	.06	<.01	1.09	<.10	.66	.53	.43
November	1.003	1.55	148	.13	<.05	<.01	.46	<.10	.10	.41	.17
December	1.001	3.98	158	.28	.04	.02	.38	<.10	.70	.38	.91
Total	14.579	44.03	10 962	3.04	1.16	0.19	12.32	1.03	12.28	9.96	6.44
Average concentration (pCi/liter)		30.2	7 510	2.0	0.8	0.1	8.5	0.7	8.4	6.8	4.4
Percent of total		100	—	7	3	<1	28	2	28	23	14
		Chlorine House (mCi)									
January	0.870	1.15	1150	<0.10	0.02	<0.01	0.10	<0.01	0.07	0.90	0.22
February	.697	1.67	466	.35	.01	<.01	.10	<.01	.39	.78	.23
March	.784	1.23	432	.18	.03	<.01	.11	<.01	.23	.68	.34
April	.760	1.34	439	.12	.02	<.01	.13	<.01	.16	.49	.18
May	1.167	1.72	1207	<.10	.02	.03	.19	.04	.09	.48	.11
June	.963	1.24	3454	<.10	.03	<.01	.15	.03	.12	.55	.15
July	1.020	1.60	598	.24	.02	<.01	.12	—	.13	.50	.24
August	1.347	1.36	546	<.10	.02	<.01	.31	<.10	.19	.51	.29
September	.552	1.04	108	.24	.01	<.01	.77	.01	.26	.27	.17
October	1.293	5.50	463	.43	.02	<.01	5.18	—	.28	.97	.36
November	.905	2.90	131	.15	.01	.01	1.33	—	<.10	.76	.40
December	.871	3.79	122	.30	.09	.02	1.18	—	.46	.69	.49
Total	11.23	24.54	9116	2.21	0.30	0.10	9.67	0.015	2.44	7.58	3.18
Average concentration (pCi/liter)		21.0	8120	2.0	0.3	0.1	8.6	0.1	2.2	6.8	2.8
Percent of total		100	—	9	1	<1	39	1	10	31	13
		Ground water (mCi)									
Total	3.360	7.36	2730	0.67	.010	0.03	2.90	0.03	0.74	2.28	0.94
Estimated error percent		±10	±10	±25	±50	±50	±10	±50	±25	±10	±25
Radiation protection standard (*1*) (pCi/liter)		600	3×10^6	2×10^6	5×10^4	1×10^5	300	6×10^4	300	2×10^4	1×10^4

[a] Includes only gamma emitters; does not include tritium.

apparent that not all of the liquid effluent flow into the sand filter beds appears in the output from them. The balance presumably mixes with the ground water flow under the beds. Estimates of the amounts of radioactivity released to the ground water in this fashion during 1971 are also shown in table 7. These were calculated on the assumption that the average concentrations of the contained nuclides corresponded to those in the observed output from the beds.

Flow, activity, and concentration information at the former site boundary and at the present site boundary are shown in table 8. Upper limit estimates of the total activity so released to ground water, based on the concentrations observed at the boundary, are also shown in table 8.

Monthly "grab" water samples were obtained at, on and offsite locations along the upper tributary of the Peconic River, into which the laboratory routinely discharges low-level radioactive wastes. Reference "grab" samples were also obtained from other nearby streams and bodies of water outside the laboratory's drainage area. The sampling locations as shown in figure 3 were as follows:

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Table 8. Liquid effluent flow, total activity and concentration of principal beta and gamma emitters at site boundary BNL (1.6 miles downstream), 1971

Month	Flow (×10^8 liters)	Concentration (mCi)									
		Gross beta [a]	^3H	^7Be	^{60}Co	^{65}Zn	^{90}Sr	^{95}Zr-Nb	^{131}I	^{137}Cs	^{144}Ce
January	0.627	0.72	716	<0.10	0.01	0.01	0.06	<0.10	0.03	0.50	0.21
February	.494	.85	270	.25	<.01	<.01	.06	.03	.21	.31	.12
March	.813	1.35	362	.39	.02	<.01	.13	.05	.13	.50	.21
April	.728	1.37	367	.23	.01	<.01	.12	.04	.08	.36	.18
May	.697	1.57	521	.43	.01	.01	.17	.08	.13	.31	.10
June	.263	.30	746	<.10	.01	<.01	.06	.01	.02	.11	.06
July	.064	.09	37	.01	<.01	<.01	.01	<.01	.01	.03	.02
August	.061	.07	27	<.01	<.01	<.01	.01	—	.01	.03	.01
September	.053	.09	15	.02	<.01	<.01	.08	<.01	.02	.02	.01
October	.067	.21	21	.03	<.01	<.01	.26	—	.01	.04	.03
November	.067	.26	10	.03	<.01	<.01	.11	—	<.01	.03	.02
December	.067	.34	9	.04	<.01	<.01	.08	—	.01	.03	.03
Total	4.001	7.22	3101	1.54	0.10	0.07	1.15	0.27	0.67	2.27	1.00
Average concentration (pCi/liter)	....	18.0	7800	3.9	0.2	0.1	3.1	0.6	1.7	5.7	2.5
Percent of total	....	100	—	21	1	1	17	3	9	31	14
	Ground water (mCi)										
Total	8.094	14.59	6 075	3.15	0.16	0.08	2.52	0.49	1.37	4.61	2.02
Estimated error (percent)	....	±10	±10	±25	±50	±50	±10	±50	±25	±10	±25
Radiation protection standard (1) (pCi/liter)	....	1000	3×10^6	2×10^6	5×10^4	1×10^5	300	6×10^4	300	2×10^4	1×10^4

[a] Includes only gamma emitters; does not include tritium.

Offsite (Peconic River, downstream)

A—Peconic River at Schultz Road, 15 900 feet

B—Peconic River at Wading River-Manorville Road, 23 100 feet

C—Peconic River at Manorville, 35 000 feet

D—Peconic River at Calverton, 46 700 feet

R—Peconic River at Riverhead, 63 500 feet

Controls (not in BNL drainage)

E—Peconic River, upstream from BNL effluent outfall

F—Peconic River, north tributary (independent of BNL drainage)

H—Carman's River—outfall of Yaphank Lake

I—Artist Lake (maintained by water table, no surface outfall)

J—Lake Panamoka (maintained by water table, no surface outfall)

The individual monthly and yearly average gross beta and tritium concentrations at the downstream and control locations are shown in table 9. A comparison suggests that the BNL effluents have little effect on the prevailing concentrations in the Peconic.

During the summer of 1971, additional sampling of the stream bottom sediment, of immersed and emergent vegetation, and of small stream fauna was conducted along the length of the Peconic. Control samples were obtained from the Carman's River. Sampling locations correspond to those used for monthly water samples. In addition, samples were obtained onsite at the following locations:

Onsite (downstream)

K—Peconic River at effluent outfall

L—Peconic River, 1300 feet below effluent outfall

L′—Peconic River, 2000 feet below effluent outfall

Table 9. Gross beta (and tritium) in downstream and control water samples, January-December 1971

Month	Gross beta concentrations (pCi/liter)									
	Downstream locations					Control locations				
	A	B	C	D	R	E	F	H	I	J
January	5	3	4	3	—	3	3	1	15	6
February	6	4	3	4	—	3	3	1	4	4
March	7	4	4	4	—	4	2	3	5	5
April	6	4	5	4	6	5	4	3	7	5
May	28	6	10	15	9	7	17	7	12	8
June	6	4	5	4	8	7	4	3	6	6
July	3	3	4	4	6	16	4	2	6	3
August	3	2	4	3	6	8	3	2	6	3
September	4	3	3	2	3	8	4	2	3	3
October	2	3	2	3	4	7	3	2	3	2
November	<1	1	5	2	4	7	5	<1	5	2
December	10	9	9	9	—	7	12	6	11	7
Average	7	4	5	5	[c] 6	7	5	3	7	5
	Tritium (nCi/liter)									
January	4	3	<1	<1	—	<1	<1	<1	<1	<1
February	<1	<1	<1	<1	—	3	<1	<1	<1	<1
March	<1	1	<1	<1	—	<1	<1	<1	<1	<1
April	<1	3	<1	<1	<1	<1	<1	<1	1	<1
May	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
June	6	4	<1	<1	<1	<1	<1	<1	<1	<1
July	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
August	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
September	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
October	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
November	<1	<1	<1	<1	<1	1	<1	<1	<1	<1
December	<1	<1	<1	<1	—	<1	<1	<1	<1	<1
Average	1	1	<1	<1	[c] <1	<1	<1	<1	<1	<1

[a] Radiation protection standard (*1*) for gross beta, 1000 pCi/liter.
[b] Radiation protection standard for tritium, 3 000 nCi/liter.
[c] Partial year.

Table 10. Gamma emitting radionuclides in Peconic River and Carman's River sediment, BNL, January-December 1971

Peconic River station	Concentration (pCi/kg)					Potassium [a] (g/kg)
	Cobalt-60	Zinc-65	Cesium-137	Thorium	Uranium	
O [b]	93	95	409	737	484	3.17
K	NA	NA	846	1300	NA	1.19
L	190	41	1230	1330	1060	4.17
L′	1030	[illegible]	3330	1650	NA	3.91
M	172	[illegible]	1590	4890	NA	3.68
Q	NA	NA	718	645	642	2.02
A	31	47	1170	668	522	1.61
B	44	81	NA	[illegible]	839	3.93
C	NA	NA	727	925	646	3.12
D	26	7	277	357	524	1.74
V	66	32	228	369	527	2.63
W	31	6	84	407	436	2.13
R	NA	NA	88	290	116	0.88
Y	NA	64	NA	509	NA	2.44
Reference (Carman's River):						
Average (2 samples)	NA	NA	187	607	427	2.69

[a] Determined from potassium-40.
[b] Sewage outlet.
NA, no analysis.

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M—Peconic River, 2600 feet below effluent outfall (at former BNL boundary)

Q—Peconic River, 6900 feet downstream (at BNL boundary).

Offsite

V—Peconic River (54 000 feet downstream)

W—Peconic River (59 600 feet downstream)

The sediment data are shown in table 10. Small concentrations of cobalt-60 and zinc-65 as well as small increments in the cesium-137, uranium, and thorium backgrounds are apparent in most samples obtained onsite and in the upper reaches of the Peconic. The corresponding vegetation data are shown in table 11. These show considerable scatter. Small concentrations of cobalt-60 and a slight excess of cesium-137 over prevailing backgrounds may have been present in vegetation in the upper reaches of the Peconic, at the BNL boundary and immediately downstream. A few samples of fish, turtles, and one of the clams were also obtained along the upper reaches of the Peconic. These data, which are shown in table 12, appear compatible to those found in vegetation. When the concentrations found in these samples are compared with radiation concentration guides, calculated on the basis of an assumed intake of 50 grams/day, the potential exposures from aquatic animals obtained from the upper reaches of the Peconic appear to be quite insignificant.

Potable water supply wells

The laboratory's potable water supply wells and cooling water supply wells are about 100 feet deep, or about 50 feet below the water table in the Long Island surface layer of glacial outwash, sand and gravel. As apparent from figure 4, most of these wells are located generally west to northwest, and therefore upstream in the local ground water flow pattern (*2*) of the laboratory's principal facilities. The exceptions are main well numbers 1 and 3, and the

Table 11. Concentrations of gamma-emitting nuclides in Peconic River and Carman's River vegetation, BNL January-December 1971

Station and type of sample	Concentration (pCi/kg)						Potassium [a] (g/kg)
	Beryllium-7	Cobalt-60	Zirconium-niobium-95	Cesium-137	Thorium	Uranium	
Carex; (sedge)							
K	1450	NA	861	1370	284	160	1.84
L	NA	NA	1050	1440	378	NA	NA
L	1920	NA	1164	1100	278	283	1.00
M	1680	NA	686	514	173	204	NA
Q	2340	NA	488	2990	252	349	.13
A	NA	NA	666	5050	NA	388	.64
B	1580	NA	740	1420	251	189	1.11
C	895	NA	551	1130	138	94	NA
D	NA	NA	NA	NA	NA	NA	NA
V	3230	NA	1330	1800	396	194	6.70
W	NA	811	1030	381	1500	NA	3.05
Y	1130	NA	750	415	953	836	4.20
Potedaria: (pickerel weed)							
C	265	NA	924	NA	89	496	1.27
D	238	NA	71	100	62	41	1.10
V	645	NA	222	NA	63	52	1.96
W	451	NA	116	106	67	63	.69
R	43	NA	96	NA	26	44	1.47
Y	109	NA	186	NA	36	28	.88
Vallisneria: (wild celery)							
M	NA	249	NA	380	208	NA	.62
C	289	NA	126	68	79	NA	1.28
D	217	30	88	57	53	53	.91
Reference vegetation: (Carman's River)							
Carex	273	NA	696	223	74	67	4.70
Miscellaneous	668	NA	315	272	124	93	5.01

[a] Potassium determined from potassium-40.
NA, no analysis.

Table 12. Environmental monitoring, concentrations of gamma-emitting nuclides in animals obtained from the Peconic River, BNL, 1971

Station and type of sample	Number of samples	Concentration (pCi/kg)					Potassium [a] (g/kg)
		Beryllium-7	Cobalt-60	Cesium-137	Thorium	Uranium	
Snapping turtle:							
L	2	220	NA	478	NA	82	0.52
M		7176	NA	1270	1586	1372	4.82
Box turtle:							
L	1	NA	NA	13 520	2500	NA	NA
Eastern painted turtle:							
M	4	348	NA	1290	422	173	NA
M		NA	NA	672	144	161	1.18
M		7860	NA	889	215	130	NA
C		190	NA	205	NA	58	1.62
Pickerel:							
M	5	NA	NA	795	352	864	NA
M		1120	NA	805	NA	416	NA
Q		NA	NA	1480	263	169	NA
A		NA	445	247	109	170	NA
A		815	NA	464	401	294	NA
Catfish:							
Q	3	1000	NA	605	443	436	NA
B		335	NA	580	164	129	NA
C		454	NA	654	205	134	1.78
Perch:							
Q	2	NA	NA	647	201	218	NA
Q		689	NA	1280	793	869	NA
Clams: (several counted together)							
C	1	129	NA	89	210	228	.31
Radiation Protection Standard [b]		9×10^7	2×10^6	9×10^5	9×10^4	9×10^6	NA

[a] Determined from potassium-40.
[b] Assumed intake of 50 g/day.
NA, no analysis.

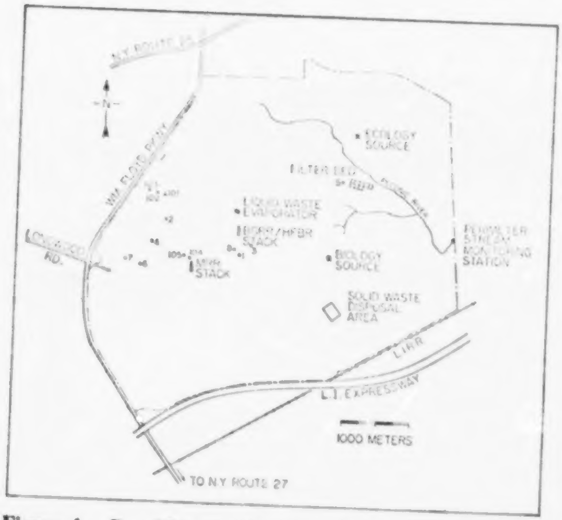
N.Y. ROUTE 25
N
WM. FLOYD PKWY
LONGWOOD RD.
ECOLOGY SOURCE
FILTER BED
5
RIVER
LIQUID WASTE EVAPORATOR
2
BGRR/HFBR STACK
6
7
8
105
MRR STACK
4
1
3
BIOLOGY SOURCE
PERIMETER STREAM MONITORING STATION
SOLID WASTE DISPOSAL AREA
LIRR
L.I. EXPRESSWAY
1000 METERS
TO N.Y. ROUTE 27

Figure 4. Brookhaven National Laboratory, potable and cooling water supply wells

small well number 5 adjacent to the sand filter beds. A total of about 5 × 10⁶ gal/day is obtained from these wells.

Monthly grab samples were scheduled for these wells. These were analyzed for gross alpha, gross beta, and tritium. All gross alpha concentrations were less than 1 pCi/liter, and all tritium concentrations were less than 1 nCi/liter. The gross beta results are set forth in table 13. There are no differences in the gross beta concentrations in these wells which might be attributed to BNL effluents.

Recharge basins

About 4×10^6 gal/day of the total water pumped from the ground water supply under the BNL site is returned to this supply in three large open recharge sumps located about 1 km north of the Liquid Waste Evaporatory Facility, about 1 km east of the HFBR, and about 1 km south of the MRR. These are monitored by routine monthly grab sampling. Their average gross beta and tritium concentrations were only very slightly in excess of those in the BNL supply wells.

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Table 13. Gross beta and tritium [a] concentrations in potable water supply wells, BNL, January-December 1971

Well number	Concentration (pCi/liter)												
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Average
1	1.0	1.0	2.6	2.1	3.5	1.4	NS	NS	NS	<1.0	<1.0	0.9	1.5
2	<1.0	<1.0	4.2	2.4	4.1	1.8	NS	NS	NS	<1.0	<1.0	2.6	1.9
3	<1.0	<1.0	1.3	2.3	2.8	2.9	NS	NS	NS	<1.0	<1.0	1.6	1.4
4	1.2	1.6	2.9	3.2	2.7	1.2	NS	NS	NS	NA	2.2	2.2	2.2
5	<1.0	<1.0	3.1	2.8	3.1	1.4	NS	NS	NS	1.2	<1.0	1.7	1.7
6	1.2	1.4	5.5	2.2	4.0	1.4	NS	NS	NS	1.3	2.8	4.7	2.8
7	<1.0	<1.0	1.5	2.7	2.7	1.1	NS	NS	NS	<1.0	2.2	1.5	1.5
101	1.0	<1.0	1.6	1.5	NA	1.2	NS	NS	NS	<1.0	1.5	.9	1.0
102	<1.0	<1.0	4.0	1.6	NA	NS	NS	NS	NS	<1.0	1.4	1.3	1.4
103	1.6	2.1	1.5	2.2	NA	NS	NS	NS	NS	1.3	1.9	2.4	1.9
104	<1.0	NA	NA	2.3	2.8	1.6	NS	NS	NS	<1.0	<1.0	<1.0	1.2
105	2.1	NA	NA	1.9	2.9	1.6	NS	NS	NS	2.1	<1.0	<1.0	1.7

Radiation protection standard (*1*): 100 pCi/liter (for unidentified nuclides, in the absence of radium-226 or radium-228).

[a] All tritium concentrations <1.0 nCi/liter.
NS, no sample.
NA, no analysis.

Ground water surveillance

Several areas from which there is a potential for the migration of radioactivity downward from the surface into the saturated zone of ground water, have been identified. Ground water sampling was routinely conducted in shallow wells located adjacent to and downstream from these areas. These areas include the sand filter beds and downstream along the Peconic River, the solid waste disposal area, the former open-pit dump and the sanitary landfill which replaced it in 1967, and the decontamination facility sump. Their locations and those of the related ground water surveillance wells are shown in figure 5.

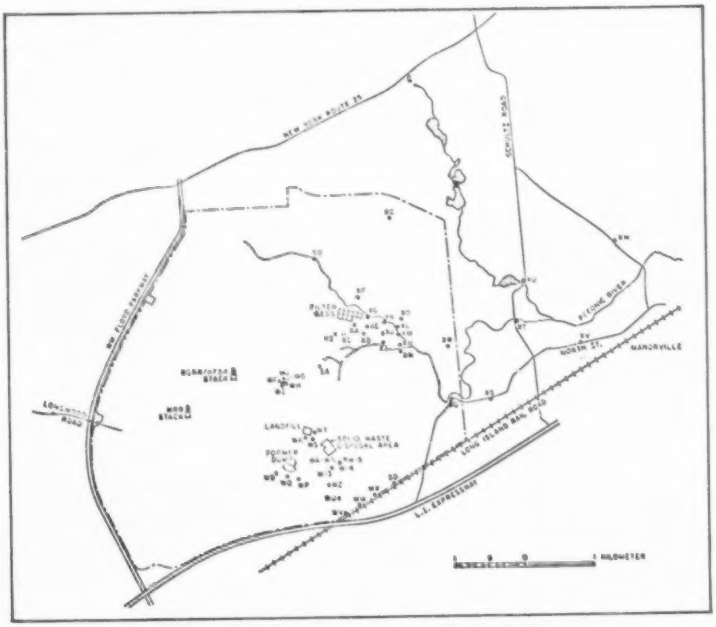
NEW YORK ROUTE 25
SCHULTZ ROAD
WM. FLOYD PARKWAY
LONGWOOD ROAD
FILTER BEDS
PECONIC RIVER
NORTH ST.
MANORVILLE
LANDFILL
SOLID WASTE DISPOSAL AREA
FORMER DUMP
LONG ISLAND RAIL ROAD
L.I. EXPRESSWAY
1 KILOMETER

Figure 5. Ground water surveillance wells
Brookhaven National Laboratory

Table 14. Radioactivity in sand filter beds and Peconic River area ground water surveillance wells BNL, January-December 1971

Well	Number of samples	Gross alpha (pCi/liter)	Number of samples	Gross beta (pCi/liter)	Number of samples	Tritium (nCi/liter)	Number of samples	Strontium-90 (pCi/liter)	Number of samples	Cesium-137 (pCi/liter)
SA	13	1.0	13	5.9	12	<1.0	2	0.2	2	<0.5
SB	11	<.5	11	1.8	10	<1.0	2	.2	2	<.5
SC	8	<.5	8	2.8	8	<1.0	NS	—	NS	—
SD	13	<.5	13	1.5	13	<1.0	NS	—	NS	—
XA	12	<.5	13	10.6	13	6.9	1	5.0	1	<.5
XB	4	1.2	4	7.5	2	.5	1	.2	1	<.5
XC	7	1.3	8	8.4	2	.5	1	3.2	1	<.5
XD	12	<.5	12	1.1	2	.4	1	<.2	1	<.5
XE	12	.7	12	2.5	12	11.0	1	.2	1	<.5
XF	7	<.5	7	2.0	1	.2	NS	—	NS	—
XG	7	<.5	7	6.0	7	4.8	1	3.1	1	.6
XH	11	<.5	11	1.7	2	.6	1	.5	1	<.5
XI	7	<.5	7	1.7	2	.2	1	.4	1	<.5
XJ	7	<.5	7	3.1	3	.3	1	1.8	1	<.5
XK	7	<.5	7	10.8	7	7.7	1	2.1	1	<.5
XL	13	1.1	13	19.9	13	10.5	1	13.0	1	<.5
XM	13	<.5	13	9.0	13	5.7	1	5.0	1	1.2
XN	7	2.2	7	6.8	3	.4	1	.8	1	<.5
XO	7	.9	7	7.1	3	.2	1	2.3	1	<.5
XQ	12	<.5	12	4.8	12	8.6	NS	—	NS	—
XR	2	.7	2	5.6	2	<1.0	NS	—	NS	—
XS	12	1.0	12	7.1	2	.3	NS	—	NS	—
XT	13	<.5	13	2.4	2	.4	NS	—	NS	—
XU	13	<.5	13	2.3	1	.4	NS	—	NS	—
XV	13	<.5	13	36.3	2	.6	NS	—	NS	—
XW	13	<.5	13	3.2	2	.6	NS	—	NS	—
Radiation protection standard (*1*).		[a] 100		[b] 300		300		300		2×10⁴

[a] If iodine-129, radium-226 and radium-220 not present.
[b] If iodine, 125,-133, strontium-90, and alpha-emitters not present.
NS, no sample.

Table 15. 1971 environmental monitoring, solid waste disposal area, landfill and dump area, and 650 sump, gross alpha gross beta, tritium, strontium-90 and cesium-137 concentrations, BNL

Well	Number of samples	Gross alpha (pCi/liter)	Number of samples	Gross beta (pCi/liter)	Number of samples	Tritium (nCi/liter)	Number of samples	Strontium-90 (pCi/liter)	Number of samples	Cesium-137 (pCi/liter)
WA	6	2.7	8	69 800	NS	—	1	326	6	68 300
WB	11	<.5	11	64	2	0.70	1	31	1	0.9
WC	12	<.5	11	17	2	.68	NS	—	NS	—
WD	12	<.5	12	19	13	3.3	NS	—	NS	—
WE	11	<.5	11	24	1	.7	1	11	1	<.5
WF	7	<.5	7	427	1	.6	1	453	1	1.4
WG	9	<.5	9	26	1	.5	1	7	1	<.5
WH	7	<.5	7	7.5	1	.5	1	3	1	2
WI	2	<.5	2	2.3	1	.4	1	4	1	.5
WJ	2	<.5	2	18	1	.5	1	7	1	<.5
WK	9	<.5	9	19	9	1.0	1	10	1	<.5
WL	9	<.5	9	130	9	.8	1	99	1	<.5
WM	9	<.5	9	8.9	9	7.8	1	.4	1	<.5
WN	10	<.5	10	3.1	3	.7	1	.2	1	<.5
WO	5	<.5	5	<1.5	1	.4	NS	—	NS	—
WP	6	<.5	6	4.0	6	2.6	NS	—	NS	—
WQ	7	<.5	7	5.3	7	2.5	NS	—	NS	—
WR	2	3.5	2	42	2	23	NS	—	NS	—
WS	6	<.5	6	1.7	2	.8	NS	—	NS	—
WT	8	<.5	8	1.6	2	.4	1	<.2	1	<.5
WU	NS		NS		NS		NS		NS	
WV	NS		NS		NS		NS		NS	
WW	2	<.5	2	3.4	2	<1.0	NS	—	NS	—
WX	2	<.5	2	3.4	2	<1.0	NS	—	NS	—
WZ	10	<.5	10	2.9	1	.6	NS	—	NS	—
W-1	1	<.5	1	93	1	.5	NS	—	NS	—
W-2	1	<.5	1	103	1	.8	NS	—	NS	—
W-3	1	<.5	1	3.9	1	<1.0	NS	—	NS	—
W-4	1	<.5	1	4.6	1	<1.0	NS	—	NS	—
W-5	1	<.5	1	1.1	1	<1.0	NS	—	NS	—
Radiation protection standard (*1*).		[a] 100		[b] 300		300		300		2×10⁴

[a] If iodine-129, radium-226, and radium-220 not present.
[b] If iodine-125,-133, strontium-90, and alpha-emitters not present.
NS, no sample.

For convenience in assessing the data, the wells have been divided into several groups. Yearly average gross alpha, gross beta, and tritium concentrations of the wells generally in the proximity of the sand filter beds and downstream on the Peconic River are summarized in table 14. At least one sample from most of these locations was also analyzed for strontium-90 and cesium-137 (by gamma analysis) during the year. Corresponding information for the wells generally in the proximity or downstream of the solid waste disposal area, the landfill and dump zones, and of the decontamination facility sump (about 1 km east of the HFBR) is summarized in table 15.

From these data, it appears that the spread of contamination in the ground water, if any, is limited to within a few hundred feet of the identified foci and that this is limited to a small percentage of the applicable Radiation Protection Standards.

Milk sampling

Monthly samples of milk were obtained from the two nearest dairy farms located 10 km south-southwest and 10 km south-southeast of Brookhaven. These samples were analyzed for gamma-emitters and then processed through an ion exchange column to improve the lower detection capability for iodine-131. The data are indicated in table 16. There is no significant difference between these and the average 1971 concentrations reported (*3*) for milk samples in the northeast region of the United States by the Environmental Protection Agency.

Grass and soil sampling

Two sets of samples, one early in the growing season and one toward its end, were collected adjacent to most of the BNL perimeter monitoring stations and from a number of offsite farms. A few onsite samples were also obtained. These were analyzed for gamma-emitting nuclides. Soil samples are primarily intended to reflect surface deposition and are therefore obtained to a depth of approximately 2.5 cm (1 inch) in an open area or after removal of root material. The data for soil are shown in table 17 and those for grass in table 18. Comparison of offsite downwind samples (6 km northeast and 10 km southeast) with other samples discloses no consistent differences. Comparison of offsite samples with onsite samples suggests the possible presence of a slight excess of cesium-137 in samples obtained at the northeast perimeter and adjacent to the solid waste disposal area.

Summary

Natural background and radiation levels in the vicinity of Brookhaven National Laboratory

Table 16. Radionuclide concentrations in milk, Brookhaven National Laboratory January-December 1971

Month	Farm B (10 km SSW)				Farm C (10 km SE)			
	Strontium-90 [a] (pCi/liter)	Iodine-131 (pCi/liter)	Cesium-137 (pCi/liter)	Potassium [b] (g/liter)	Strontium-90 [a] (pCi/liter)	Iodine-131 (pCi/liter)	Cesium-137 (pCi/liter)	Potassium [b] (g/liter)
January		<5	16	1.42	NA	<5	18	1.33
February		<5	22	1.41	NA	<5	24	1.48
March	5	<5	24	1.41	10	<5	14	1.16
April		<5	12	1.35	NA	<5	10	1.21
May		<5	23	1.47	NA	<5	20	1.15
June	6	<5	27	1.44	5	<5	20	1.35
July		<5	16	1.32	NA	<5	15	1.21
August		<5	23	1.61	NA	<5	22	1.29
September	6	<5	20	1.00	11	<5	20	1.93
October		<5	15	1.34	NA	<5	22	1.49
November		<5	15	1.15	NA	<5	14	1.41
December	<3	<5	13	1.50	10	<5	11	1.25
Average	5	<5	19	1.37	9	<5	18	1.32
Radiation protection standard (*1*)	[c] 200	[c] 100	4×10^4	—	[c] 200	100	4×10^4	—

[a] Quarterly data of New York State Health Department (*4*).

[b] Potassium determined from potassium-40. Potassium in g/iiter.

[c] Based on FRC Radiation Protection Guide (*5*) and an assumed intake of 1 liter/day.

NA, no analysis.

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Table 17. Concentration of gamma-emitting nuclides in soil, BNL, January-December 1971

Location	Sampling month	Concentration (pCi/kg)					Potassium [a] (g/kg)
		Zirconium-niobium-95	Cesium-137	Cerium-144	Uranium	Thorium	
Offsite:							
Farm A, 3 km NW	June	810	4250	4710	1260	2460	7.90
	Sept	232	484	4490	1630	1760	11.50
Farm B, 10 km SSW	June	580	<500	2080	710	527	5.75
	Sept	311	521	2820	833	930	7.09
Farm C, 10 km SE	June	525	2060	2670	955	634	4.40
	Sept	184	1560	2340	865	950	4.35
Farm D, 15 km NW	June	453	1800	4320	1115	1255	9.70
	Sept	240	1760	4360	1800	2110	11.50
Farm H, 6 km NE	June	505	735	1735	730	550	5.14
	Sept	314	820	2220	582	650	4.85
Onsite:							
Northwest perimeter	June	191	443	<1000	975	1050	7.70
	Aug	304	413	2260	1295	1760	8.10
Southwest perimeter	June	335	2220	<1000	961	1410	7.81
	Aug	268	515	2390	1570	1590	10.00
Southeast perimeter	June	587	1350	<1000	712	1155	9.90
	Aug	1020	725	3060	1070	1380	9.01
Northeast perimeter	June	510	4700	<1000	3470	3880	17.30
	Aug	396	3140	3620	2470	2660	14.00
Solid waste disposal area	Sept	—	3620	NA	1290	1750	8.27
SW ecology forest	Sept	297	546	1630	707	808	5.07
Estimated error (percent)		±25	±25	±25	±25	±25	±25

[a] Potassium determined from potassium-40.
NA, no analysis.

Table 18. Concentration of gamma-emitting nuclides in grass, BNL, January-December 1971

Location	Sampling month	Concentration (pCi/kg)							Potassium [a] (g/kg)
		Beryllium-7	Zinc-65	Zirconium-niobiun-95	Cesium-137	Cerium-144	Uranium	Thorium	
Off site:									
Farm A, 3 km NW	June	970	68	391	195	425	NA	NA	4.10
	Sept	1470	96	306	107	1075	177	324	6.10
Farm B, 10 km SSW	June	985	61	440	69	535	NA	NA	4.28
	Sept	732	95	111	75	471	<100	131	5.68
Farm C, 10 km SSE	June	705	75	316	196	<500	NA	NA	4.55
	Sept	1590	121	303	199	1020	<100	258	5.07
Farm D, 15 km NW	June	823	89	440	118	559	NA	NA	5.22
	Sept	580	104	132	125	715	199	230	5.25
Farm H, 6 km NE	June	1620	95	825	218	1190	NA	NA	5.30
	Sept	1760	79	442	145	1170	<100	<100	5.22
Onsite:									
Northwest perimeter	June	NS	NS	NS	NS	NS	NS	NS	NS
	Aug	2430	130	1020	289	2460	NA	NA	3.92
Southwest perimeter	June	1560	<50	795	204	438	NA	NA	4.41
	Aug	1160	119	352	87	759	NA	NA	5.55
Southeast perimeter	June	NS	NS	NS	NS	NS	NS	NS	NS
	Aug	1035	106	410	177	292	NA	NA	4.70
Northeast perimeter	June	2070	133	1115	233	1680	NA	NA	6.00
	Aug	1720	88	727	381	1260	NA	NA	3.94
Solid waste disposal area	Sept	1650	111	306	403	396	NA	NA	6.96
SW ecology forest	Sept	2260	96	426	220	469	NA	NA	3.92
Estimated error (percent)		±25	±50	±25	±25	±25			±25

[a] Potassium determined from potassium-40.
NA, no analysis.
NS, no sample.

attributable to its operations during 1971 are summarized in this report. Among the data reported are external radiation levels, air particulate, tritium, and radioiodine concentrations, precipitation, liquid effluent-related concentrations in stream, ground water and surveillance wells, milk, grass, and soil samples.

External radiation levels at the north boundary of the laboratory, attributable to an ecology forest irradiation source, were 16 mR/year, or 3 percent of the applicable radiation protection standard (*1*). Other than tritium, there was no indication of BNL effluents in environmental air and precipitation samples. In air, the largest BNL effluent-related tritium concentration was 8 pCi/m^3, which is 0.004 percent of the AEC standard. In precipitation, it was 300 nCi/liter, which is 0.01 percent of the drinking water standard.

About 75 percent of the volume of liquid effluent released onto the sand filter beds at the BNL sewage treatment plant is recovered and flows into the headwaters of the Peconic River, while about 25 percent of its flows into the ground water underlying the beds. The gross concentration of beta and gamma-emitters in it was 4 percent of the applicable radiation standard. Tritium, which is measured separately, was 0.3 percent of its standard.

Of the input from the sand filter beds to the Peconic River, 65 percent permeated into the ground water underlying the stream bed between the point of release and the laboratory perimeter, while 35 percent flowed over the measuring weir at the boundary. The gross beta and gamma-emitter concentration at the site boundary was 2 percent of the AEC standard, while that of tritium was 0.3 percent of its standard.

At downstream locations, the largest yearly average gross beta concentration in monthly grab samples was 0.7 percent of the AEC standard, while that of tritium was 0.1 percent of its standard. The downstream gross beta concentrations were not significantly different from those measured at remote "control" stream locations.

Seasonal sampling of Peconic River bottom sediments, stream vegetation and of miscellaneous aquatic fauna indicated that small concentrations of cobalt-60 ($<$1000 pCi/kg), and a slight excess ($<$10 000 pCi/kg) of cesium-137 above prevailing fallout background, were present in some samples obtained in the upper reaches of the Peconic, onsite and a few miles downstream. These concentrations are insignificant ($<$1 percent) relative to calculated concentration guides.

Routine grab samples from the laboratory's potable and cooling water supply wells disclosed no consistent differences between those upstream in ground water flow and those downstream from the principal laboratory facilities. The gross beta concentration of the large volume of cooling water released to onsite sumps was only very slightly above that of the supply wells.

Ground water surveillance was conducted adjacent to identified areas from which there is a potential for the migration of radioactivity. Immediately adjacent to the sand filter beds and the Peconic River onsite, gross alpha, gross beta, strontium, and tritium concentrations up to a few percent of the applicable radiation protection standards were found.

Onsite in wells adjacent to a decontamination facility drain sump, and adjacent to the solid waste disposal area, a few gross beta, strontium-90 and cesium-137 concentrations were found in excess of offsite radiation protection standards. However, these appear to be very local, and concentrations in perimeter wells were generally only a few percent of the standards.

Monthly milk samples were obtained from two nearby dairy farms. No significant differences between these and those generally prevailing in the northeast United States were apparent. Two sets of grass and soil samples were also collected from these and three other farms, as well as from perimeter and onsite locations. There was no significant difference between offsite samples generally downwind and those generally upwind of Brookhaven. A possible small excess of cesium-137 was apparent at the BNL northeast perimeter and adjacent to the solid waste disposal area, compared to other samples.

Recent coverage in *Radiation Data and Reports:*

Period	Issue
July–December 1970	February 1973

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2. Oak Ridge Area,[3] January–December 1971

Union Carbide Nuclear Division
Oak Ridge, Tenn.

The Oak Ridge area incorporates three separate operating facilities, the Oak Ridge National Laboratory (ORNL), the Oak Ridge Gaseous Diffusion Plant (ORGDP), and the Y-12 Plant, all of which are operated by Union Carbide Corporation, Nuclear Division. In addition, two smaller Atomic Energy Commission (AEC) facilities are in the area—the UT-AEC Agricultural Research Station and Oak Ridge Associated Universities.

Oak Ridge National Laboratory is a large multipurpose research laboratory whose basic mission is the discovery of new knowledge, both basic and applied, in all areas related to nuclear energy. To accomplish this mission, the laboratory conducts research in all fields of modern science and technology. The laboratory's facilities consist of nuclear reactors, chemical pilot plants, research laboratories, radioisotope production laboratories, and support facilities.

The Oak Ridge Gaseous Diffusion Plant is a complex of production, research, development, and supporting facilities, distributed over a 640-area of eastern Tennessee. The primary mission of the plant is the enrichment of uranium hexafluoride in the uranium-235 isotope, with the performance of other atomic energy related activities as required by the Atomic Energy Commission. The principal process facilities are the five gaseous diffusion cascade buildings, portions of which are now on standby. These are supplemented by about 70 support buildings and facilities (maintenance, supply stores, administration, cafeteria, data processing, etc.). Union Carbide Corporation, Nuclear Division has been responsible for operating the Oak Ridge Gaseous Diffusion Plant since its inception.

The Oak Ridge Y-12 Plant occupies approximately 500 acres and is located immediately adjacent to the city of Oak Ridge, Tenn. It is about 2½ miles long and ¼ mile wide. The Y-12 Plant has four major responsibilities: (1) production of atomic weapons components, (2) fabrication support for weapon design agencies, (3) support for the Oak Ridge National Laboratory, and (4) support and assistance to other government agencies. Activities associated with these functions include the production of lithium compounds, the recovery of enriched uranium from unirradiated scrap material and

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[3] Summarized from Environmental Monitoring Report, U.S. Atomic Energy Commission, "Oak Ridge Facilities, Calendar Year 1971."

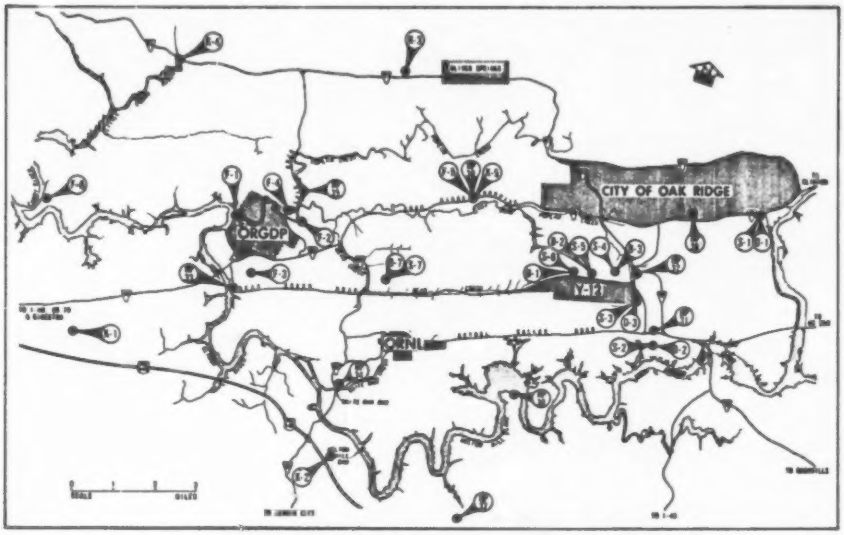

Figure 6. Locations of air monitoring stations, Oak Ridge area

the fabrication of uranium and other materials into finished parts and assemblies.

Air monitoring

Atmospheric contamination by radioactive materials occurring in the general environment of east Tennessee is monitored by two systems of monitoring stations. One system consists of nine stations (HP-31 through HP-39) which encircle the perimeter of the Oak Ridge area and provides data for evaluating releases from Oak Ridge facilities to the immediate environment (figure 6). A second system consists of eight stations (HP-51 through HP-58) encircling the Oak Ridge area at distances from 12 to 75 miles (figure 7). This system provides background data to aid in evaluating local conditions. Sampling for radioactive particulates is carried out by passing air continuously through filter papers. Filter papers are evaluated by gross beta and gross alpha counting techniques for normal operations. More detailed analyses are performed when concentrations in the environment are significantly above normal. Airborne radioactive iodine is monitored by passing air continuously through cartridges containing activated charcoal. Charcoal cartridges are evaluated for radioactive iodine by gamma spectrometry.

Data on the concentrations of radioactive materials in air in the Oak Ridge and surrounding areas are given in tables 19 through 21. The average gross beta concentrations of radioactivity from particulates in air measured by the perimeter and remote monitoring systems were less than 0.23 percent and 0.23 percent, respectively, of the AEC standards (*6*), for individuals in uncontrolled areas (table 19). The average gross alpha concentrations were less than 0.05 percent of the concentration guide for natural uranium in both systems (table 20). The average concentration of iodine-131 measured by the perimeter air monitoring system was less than 0.01 percent of the inhalation concentration guide for individuals in uncontrolled areas (table 21).

Table 19. Long-lived gross beta radioactivity in airborne particulates, ORNL, January-December 1971

Station number	Location	Number of samples	Concentration (fCi/m³) Maximum [a]	Minimum [b]	Average	Percent of AEC standard [c]
Perimeter stations [d]						
HP-31	Kerr Hollow Gate	52	640	35	220	0.22
HP-32	Midway Gate	52	720	<3	<230	<.23
HP-33	Gallaher Gate	52	820	<3	<200	<.20
HP-34	White Oak Dam	52	700	<3	<220	<.22
HP-35	Blair Gate	52	840	23	230	.23
HP-36	Turnpike Gate	[e] 249	800	10	260	.26
HP-37	Hickory Creek Bend	52	690	<3	<190	<.19
HP-38	East of EGCR	52	660	<3	<230	<.23
HP-39	Townsite	52	880	13	250	.25
Average			750	<11	<230	<.23
Remote stations [f]						
HP-51	Norris Dam	51	720	28	220	0.22
HP-52	Loudoun Dam	51	760	28	230	.23
HP-53	Douglas Dam	52	650	3	220	.22
HP-54	Cherokee Dam	51	750	33	230	.23
HP-55	Watts Bar Dam	52	820	29	250	.25
HP-56	Great Falls Dam	52	670	24	240	.24
HP-57	Dale Hollow Dam	52	680	34	220	.22
HP-58	Knoxville	48	670	4	220	.22
Average			720	23	230	.23

[a] Maximum weekly average concentration.
[b] Minimum weekly average concentration—minimum detectable level is 5 pCi/sample.
[c] AEC standard is 100 pCi/m³ for unidentified radionuclides (AEC Manual, Appendix 0524, Annex A, Table II).
[d] Figure 6.
[e] Samples collected 5 days per week.
[f] Figure 7

Table 20. Long-lived gross alpha radioactivity in air, ORNL, January-December 1971

Station number	Location	Number of samples	Concentration (fCi/m³) Maximum [a]	Minimum [b]	Average	Percent of AEC standard [c]
Perimeter stations: [d]						
HP-31	Kerr Hollow Gate	52	5	<1	<1	<0.05
HP-32	Midway Gate	52	5	<1	<2	<.10
HP-33	Gallaher Gate	52	7	<1	<1	<.05
HP-34	White Oak Dam	52	4	<1	<1	<.05
HP-35	Blair Gate	52	5	<1	<1	<.05
HP-36	Turnpike Gate	[e] 249	14	<1	<4	<.20
HP-37	Hickory Creek Bend	52	2	<1	<1	<.05
HP-38	East of EGCR	52	5	<1	<2	<.10
HP-39	Townsite	52	3	<1	<1	<.05
Average			6	<1	<1	<.05
Remote stations [f]:						
HP-51	Norris Dam	51	3	<1	<1	<0.05
HP-52	Loudoun Dam	51	4	<1	<1	<.05
HP-53	Douglas Dam	52	5	<1	<1	<.05
HP-54	Cherokee Dam	51	4	<1	<1	<.05
HP-55	Watts Bar Dam	52	5	<1	<1	<.05
HP-56	Great Falls Dam	52	3	<1	<1	<.05
HP-57	Dale Hollow Dam	52	3	<1	<1	<.05
HP-58	Knoxville	48	5	<1	<1	<.05
Average			4	<1	<1	<0.05

[a] Maximum weekly average concentration.
[b] Minimum weekly average concentration—minimum detectable level is 2 pCi/sample.
[c] AEC standard is 2.0 pCi/m³ for natural uranium (AEC Manual, Appendix 0524, Annex A, Table II).
[d] See figure 6.
[e] Samples collected 5 days per week.
[f] See figure 7.

Table 21. Concentration of iodine-131 in air as measured by the perimeter air monitoring stations,[a] ORNL January-December 1971

Number of samples	Concentration (fCi/m^3)			Percent of AEC standard [c]
	Maximum	Minimum [b]	Average	
468	61	<6	<11	<0.01

[a] See figure 6.
[b] Minimum detectable amount of iodine-131 is 10 pCi/sample.
[c] AEC standard is 100 pCi/m^3 (AEC Manual, Appendix 0524, Annex A, Table II).

The uniform level of filterable activity measured by the perimeter and remote stations indicated that the activity was of nonplant origin. While some iodine-131 was released to the atmosphere during the year, measurements in the Oak Ridge area showed that environmental concentrations were well below established standards.

Water monitoring

Liquid wastes originating at the three major Oak Ridge facilities are discharged, after treatment, to White Oak Creek, Poplar Creek, East Fork Poplar Creek, and Bear Creek which are small tributaries to the Clinch River.

A continuous proportional sample is collected at White Oak Dam (Station W-1), which is the last onsite control point prior to the entry of White Oak Creek into the Clinch River, and composited for monthly analysis. Continuous proportional samples are collected in the Clinch River at Melton Hill Dam (Station C-2) 2.3 miles above White Oak Creek outfall and at the ORGDP water intake (Station C-3) 6.3 miles downstream from the entry of White Oak Creek. A grab sample is collected daily from the Clinch River at Center's Ferry near Kingston, Tenn. (Station C-5), figure 7. Clinch River samples are composited for quarterly analysis.

The concentrations of radionuclides present in detectably significant amounts are determined by specific radionuclide analysis and gamma spectrometry. The concentration of each radionuclide is compared with its respective concentration guide (CG) value as specified in the AEC Manual, Appendix 0524, and the resulting fractions are summed to obtain the percent of the AEC standard in the Clinch River.

Water samples are collected in Poplar Creek upstream of the ORGDP (Station P-1), in Poplar Creek downstream from the ORGDP waste discharges (Station P-2), and in the Clinch Rivdr downstream from the Poplar Creek outfall (Station C4) (figure 7). Semi-

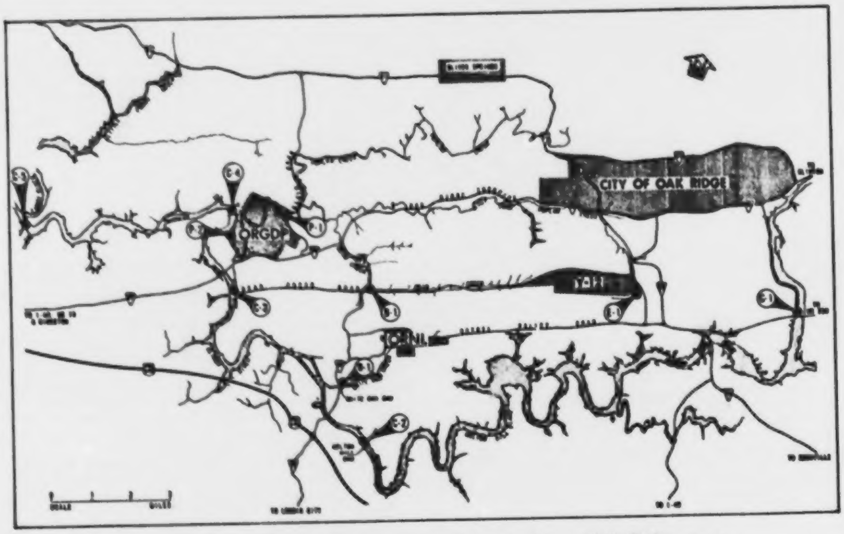

Figure 7. Locations of stream monitoring stations, Oak Ridge area

Table 22. Radionuclides in the Clinch River, ORNL, January-December 1971

Sampling location	Number of samples	Range	Concentration (pCi/liter)							Percent of AEC standard [c]
			^{90}Sr	^{144}Ce	^{137}Cs	$^{103,-106}$Ru	^{60}Co	^{95}Zr-Nb	Tritium	
C2 CRM 23.1 [a]	4	Maximum	0.7	0.5	0.3	1.8	0.4	0.2	<1000	
		Minimum	.3	.1	<.1	.7	.1	<.1	<1000	
		Average	.5	.3	<.1	1.2	.3	<.1	<1000	<0.21
W1 CRM 20.8 [b]	12	Maximum	1.8	<.1	.6	.3	.5	<.1	5160	
		Minimum	.2	<.1	<.1	<.1	<.1	<.1	510	
		Average	.5	<.1	.1	<.1	<.1	<.1	1150	<.20
C3 CRM 14.5 [a]	4	Maximum	2.7	.7	.0	4.8	.9	.5	6580	
		Minimum	1.4	<.1	.6	1.0	.3	<.1	<1000	
		Average	1.8	<.3	1.3	2.7	.6	<.2	<2970	<.75
C5 CRM 4.5 [a]	4	Maximum	1.4	.5	1.3	2.3	1.9	.3	5180	
		Minimum	.5	.1	.5	.5	.2	<.1	<1000	
		Average	1.0	.3	.9	2.0	.8	<.1	<2210	<.45

[a] Measured values.

[b] Values given for this location are calculated values based on the concentrations measured at White Oak Dam and the dilution afforded by the Clinch River. They do not include radioactive materials (e.g., fallout) that may enter the river upstream of White Oak Creek outfall (CRM 20.8).

[c] Applicable concentration guides and the method for calculating percent of concentration guide for a known mixture of radionuclides are given in AEC Manual, Appendix 0524, Annex A.

annual grab samples are collected in Poplar Creek to verify the continued compliance demonstrated by continuous samples taken over a 12-year period. A continuous sample is collected in the Clinch River and composited over a 3-month period for analysis. Samples are analyzed for uranium by the fluorometric method.

Continuous proportional water samples are collected at the outlet of New Hope Road on East Fork Poplar Creek (Station E-1). Weekly grab samples were collected on Bear Creek (Station B-1) during the first 9 months of 1971 (figure 7) while the last 3 month's samples were obtained by a continuous proportional sampler. Samples are analyzed on a monthly basis by gross alpha counting techniques.

The average concentrations of specific radionuclides in the Clinch River at all points of measurement were less than 1 percent of the applicable concentration guides for uncontrolled areas (table 22). The average concentration of transuranic alpha emitters in the Clinch River at CRM 20.8 was 5 fCi/liter which is less than 0.01 percent of the concentration guide for water in uncontrolled areas containing an unknown mixture of radionuclides.[4] Average concentrations of uranium in the surface streams in the Oak Ridge area were no greater than 1.2 percent of the applicable concentration guide for uncontrolled areas (table 23).

Table 23. Uranium concentration in surface streams ORNL, January-December 1971

Station number [a]	Location	Number of samles	Concentration (pCi/liter)			Percent of AEC standard [b]
			Maximum	Minimum	Average	
P-1	Poplar Creek	2	40	10	25	0.1
P-2	Poplar Creek	2	130	13	71	.3
C-4	Clinch River	4	6	0	3	<.1
E-1	East Fork Poplar Creek	12	400	160	240	1.2
B-1	Bear Creek	12	700	100	230	1.2

[a] See figure 8.

[b] AEC standard is 20 nCi/liter (AEC Manual, Appendix 0524, Annex A, Table II).

Milk monitoring

Raw milk is monitored for iodine-131 and strontium-90 by the collection and analysis of samples from 12 sampling stations located within a radius of 50 miles of Oak Ridge. Samples are collected weekly at each of eight stations located near the Oak Ridge area. Four stations, located more remotely with respect to Oak Ridge operations, are sampled at a rate of one station each week. Milk sampling locations for the eight stations near the Oak Ridge area are shown in figure 8. Samples are analyzed by ion exchange techniques and results are compared to intake guides specified by the Federal Radiation Council (FRC) (*7*).

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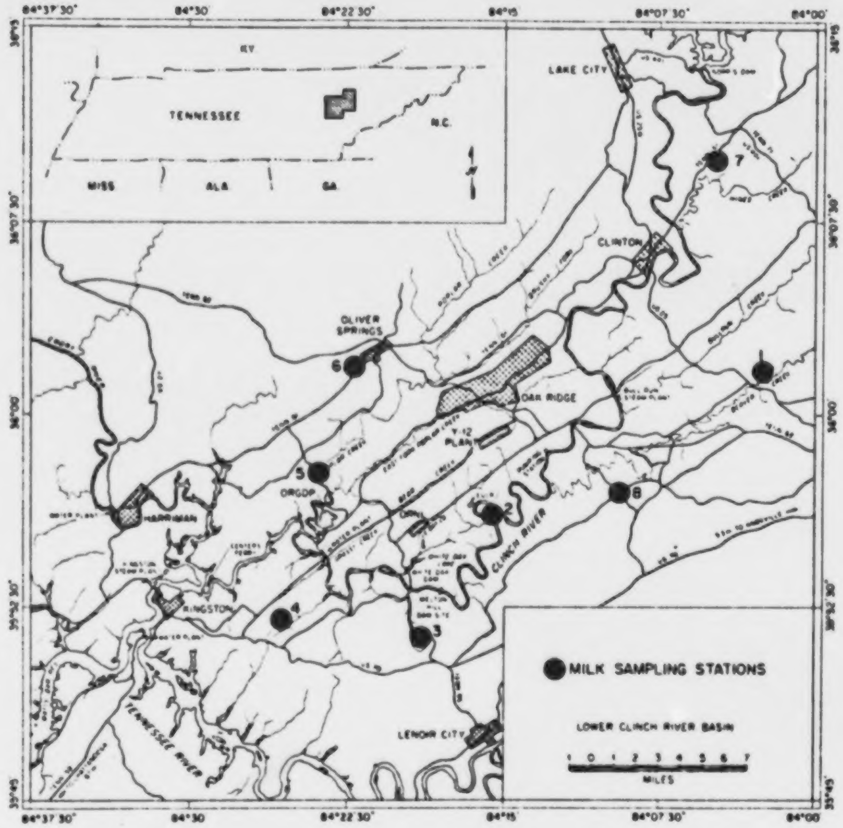
[4] AEC Radiation Protection Standard—100 pCi/liter (*16*).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KY.
TENNESSEE
N.C.
MISS
ALA
GA
LAKE CITY
CLINTON
OLIVER SPRINGS
OAK RIDGE
Y-12 PLANT
ORGDP
HARRIMAN
KINGSTON
LENOIR CITY
CLINCH RIVER
TENNESSEE RIVER
1
2
3
4
5
6
7
8
MILK SAMPLING STATIONS
LOWER CLINCH RIVER BASIN
1 0 1 2 3 4 5 6 7
MILES

Figure 8. Locations of milk sampling stations, Oak Ridge area

The average concentrations of iodine-131 and strontium-90 in raw milk are given in tables 24 and 25. If one assumes the average intake of milk per individual to be 1 liter per day, the average concentration of iodine-131 in the milk in the immediate environs of the Oak Ridge area was just above the lower limit of FRC Range II. The average concentration in the environs remote from Oak Ridge was within FRC Range I. The average concentrations of strontium-90 in milk from both the immediate and remote environs were within the FRC Range I. The average concentrations measured in the Oak Ridge area do not differ significantly from the values in the southeastern United States reported by the Environmental Protection Agency's Pasteurized Milk Network.

Table 24. Concentration of iodine-131 in raw milk, ORNL January-December 1971

Location	Number of samples	Concentration (pCi/liter)			Comparison with standard [b]
		Maximum	Minimum [a]	Average	
Immediate environs [c]	389	21	<10	<10.1	FRC Range II
Remote environs	38	<10	<10	<10	FRC Range I

[a] Minimum detectable concentration of iodine-131 is 10 pCi/liter.

[b] Applicable FRC standard, assuming 1 liter per day intake:
Range I: 0 to 10 pCi/liter—adequate surveillance required to confirm calculated intakes.
Range II: 10 to 100 pCi/liter—active surveillance required.
Range III: 100 to 1 000 pCi/liter—positive control action required.
Note: Upper limit of Range II can be considered the concentration guide.

[c] See figure 8.

Table 25. Concentration of strontium-90 in raw milk ORNL, January-December 1971

Location	Number of samples	Concentration (pCi/liter)			Comparison with standard [b]
		Maximum	Minimum [a]	Average	
Immediate environs [c]	389	32	2.4	11.4	FRC Range I
Remote environs	38	15	6.8	9.4	FRC Range I

[a] Minimum detectable concentration of strontium-90 in milk is 2 pCi/liter.

[b] Appicable FRC standard, assuming 1 liter per day intake:

Range I: 0 to 20 pCi/liter—adequate surveillance required to confirm calculated intakes.

Range II: 20 to 200 pCi/liter—active surveillance required.

Range III: 200 to 2000 pCi/liter—positive control action required.

Note: Upper limit of Range II can be considered the concentration guide.

[c] See figure 8.

Fish sampling

Two species of fish from the Clinch River are sampled during the spring and summer of each year. The fish are prepared for radiochemical analysis in a manner analogous to human utilization. Ten fish of each species are composited for each sample and the samples are analyzed by gamma spectrometry and radiochemical techniques for the critical radionuclides contributing significantly to the potential radiation dose to man. An estimate of man's intake of radionuclides from eating Clinch River fish is made by assuming an annual rate of fish consumption of 14 pounds (*8*) and the estimated percentage of maximum permissible intake is calculated by assuming a maximum permissible intake of radionuclides from eating fish to be comparable to a daily intake of 2.2 liters (*9*) of water containing the concentration guide of the radionuclides in question, for a period of 1 year.

Data on the concentrations of radionuclides in Clinch River fish are given in table 26. The levels measured were less than 1 percent of that required to obtain an estimated maximum permissible intake.

Table 26. Radionuclide content of Clinch River fish ORNL, January-December 1971

Species	Number of samples [a]	Concentration (pCi/kg wet weight)			Estimated percent of MPI [b]
		^{90}Sr	^{106}Ru	^{137}Cs	
White crappie	1	135	<180	343	<0.38
Small mouth buffalo	1	108	<315	336	<.32

[a] Composite of 10 fish in each species.

[b] Maximum permissible intake—assumes intake of radionuclides from eating fish to be comparable to a daily intake of 2.2 liters of water for the year containing the concentration guide level of the radionuclides in question.

Flora and soil

Soil samples are collected annually from near the perimeter air monitoring stations (figure 6). Four samples, approximately 8 cm in diameter and 1 cm thick, are collected in a 1 m^2 area at each location, composited, and analyzed radiochemically for uranium and plutonium content to determine historical background information.

Soil, pine needle, and grass samples are collected semiannually from five sampling locations (K-1 through K-5) located on a 5-mile radius from the ORGDP Plant (figure 6). Samples are analyzed for uranium by the fluorometric method. Data on uranium concentrations in soil and flora are given in tables 27 and 28.

Table 27. Soil samples taken near perimeter air monitoring stations, ORNL, January-December 1971

Sampling location [a]	Number of samples [b]	Concentration (fCi/g dry soil) [c]	
		Plutonium (α)	Uranium
HP-31	1	33	110
HP-32	1	28	70
HP-33	1	24	230
HP-34	1	38	230
HP-35	1	47	320
HP-36	1	24	290
HP-37	1	14	140
HP-38	1	28	140
HP-39	1	52	630

[a] See figure 6.

[b] Four samples, approximately 8 cm in diameter and 1 centimeter thick, collected in a 1 m^2 area at each location and composited for analysis.

[c] Applicable concentration guides for soil contamination have not been established.

Summary

The monitoring program for the Oak Ridge area includes sampling and analysis of air, water from surface streams, several food products, flora, and soil from radioactive materials.

Surveillance of radioactivity in the Oak Ridge environs indicated that the atmospheric concentrations of radioactivity were not significantly different from other areas in east Tennessee. Concentrations of radioactivity in the

Table 28. Uranium in soil, pine needles, and grasses at 5-mile radius from ORGDP, January-December 1971

Substance	Location [a]	Number of samples	Concentration (fCi/g)		
			Maximum	Minimum	Average
Soil [b]	K-1	2	700	150	425
	K-2	2	650	350	500
	K-3	2	400	350	375
	K-4	2	450	400	425
	K-5	2	650	400	525
Pine needles [c]	K-1	2	100	50	75
	K-2	2	100	35	67
	K-3	2	200	35	117
	K-4	2	200	35	117
	K-5	2	250	35	142
Grass [c]	K-1	2	350	50	200
	K-2	2	250	100	175
	K-3	2	150	35	92
	K-4	2	200	50	125
	K-5	2	300	35	167

[a] See figure 6.
[b] Top 5 cm of soil on a dry basis.
[c] Dry basis.
Note: Applicable guides for flora and soil have not been established.

Clinch River and in fish collected from the river were less than 1 percent of the permissible concentration and intake guides for individuals in neighboring populations. Only very low level radioactivity is being released to the environment from plant operations and the resulting concentrations in all of the media sampled were well below permissible standards.

REFERENCES

(6) U.S. ATOMIC ENERGY COMMISSION. AEC manual standards for radiation protection, Chapter 0524, Annex A. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (February 1969).
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(8) U.S. DEPARTMENT OF AGRICULTURE. Department of Agriculture, agricultural statistics, 1969. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (1969).
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Previous coverage in *Radiation Data and Reports:*

Period	Issue
July-December 1970	December 1973

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3. Pinellas Peninsula Plant [5]
July–December 1971

General Electric Company
St. Petersburg, Fla.

The Pinella Peninsula Plant (figure 9) is an electronic component production facility. The plant maintains an environmental monitoring program to measure the levels of radioactive environmental contamination associated with plant effluents. These measurements serve as an index of the effectiveness of the plant's contamination control measures. Sewer effluent, surface water, milk and air within 6 miles of the plant are monitored for radioactivity. The radioactivity concentrations, weighted by atmospheric and stream dilution factors, are compared against the AEC standards for continuous nonoccupational exposure as presented in AEC Manual chapter 0524.

Combined sewer effluent

Waste water discharges from the plant were routinely sampled for radioactive material content at the site's boundary. A total of 147 samples were obtained and analyzed for tritium content. In those instances where detectable concentrations occurred, the radioactivity resulted from controlled releases. Radioactivity

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[5] Summarized from "Environmental Monitoring Report, Pinellas Plant, 1971."

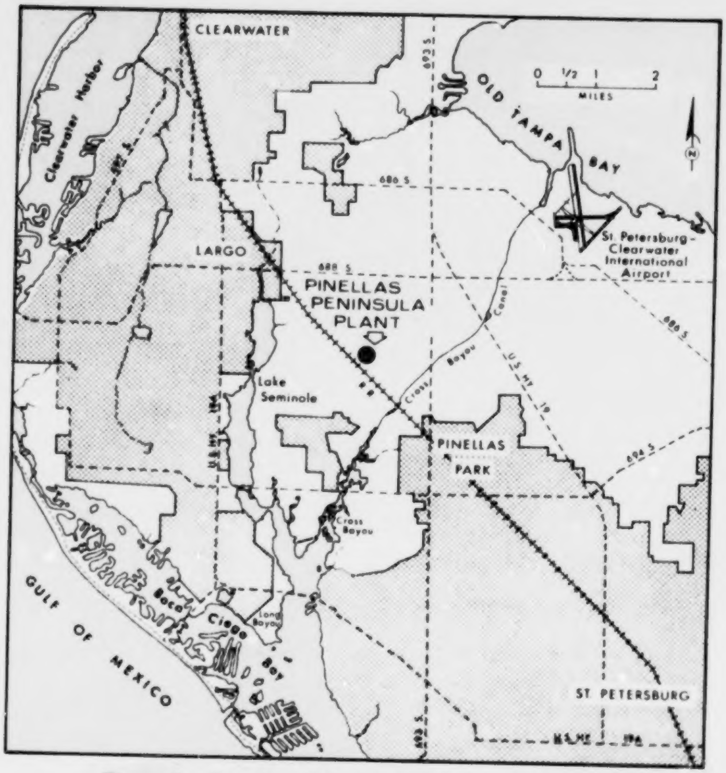
CLEARWATER
Clearwater Harbor
OLD TAMPA BAY
0 1/2 1 2
MILES
N
686 S
St. Petersburg-Clearwater International Airport
LARGO
688 S
PINELLAS PENINSULA PLANT
Cross Bayou Canal
U.S. Hy 19
Lake Seminole
PINELLAS PARK
694 S
Cross Bayou
Long Bayou
Boca Ciega Bay
GULF OF MEXICO
ST. PETERSBURG
U.S. Hy 19A
693 S

Figure 9. Location of the Pinellas Peninsula Plant

releases from the process waste system into the plant's water effluents resulted in an average tritium concentration for the period, of less than 0.6 percent of the AEC standard for continuous nonoccupational exposure.

Milk samples

Analyses of 10 raw milk samples provided by the Pinellas County Health Department from the one local diary farm revealed no detectable concentrations (<20 nCi/liter) of tritium.

Air samples

A total of four ambient air samples were obtained downwind from the plant site for tritium analysis during times of radioactivity releases. Analyses of these samples revealed that the maximum level, occurring over a period of 30 minutes, represented 0.3 percent of the tritium oxide in air concentration for continuous nonoccupational exposure.

Surface water

There were no indications of tritium in 138 routine surface water samples collected from areas surrounding the plant. These sample locations represent an area up to 6 miles in all directions from the plant site, and are not related to the waste water effluent from the plant.

Previous coverage in *Radiation Data and Reports:*

Period	Issue
January–June 1971	September 1972

Erratum

On page 101 of the Savannah River Plant article in the February 1974 issue of *Radiation Data and Reports*, a typographical error occurred in the second paragraph under the subheading *"Deer."* The fourth sentence in this paragraph should read:

"Edible meat from the deer containing 48 pCi/g would weigh about 40 pounds and would therefore contain about 0.87 *μCi* of cesium-137."

Reported Nuclear Detonations, June 1974

(Includes seismic signals presumably from foreign nuclear detonations)

The Peoples Republic of China set off a nuclear explosion in the atmosphere at about 2:00 a.m. EDT on June 17, 1974, at their Lop Nor nuclear test area in northwest China. The yield was in the range of 200 kilotons to 1 megaton.

The United Kingdom announced that an underground nuclear test had been conducted sometime during June 1974 at the Nevada Test Site in the United States. No yield was announced.

There were no nuclear detonations for the United States reported by the U.S. Atomic Energy Commission for June 1974.

Not all of the nuclear detonations in the United States are announced immediately, therefore, the information in this section may not be complete. A complete list of announced U.S. nuclear detonations may be obtained upon request from the Division of Public Information, U.S. Atomic Energy Commission, Washington, D.C. 20545.

SYNOPSES

Synopses of reports, incorporating a list of key words, are furnished below in reference card format for the convenience of readers who may wish to clip them for their files.

ENVIRONMENTAL RADIATION EFFECTS OF NUCLEAR FACILITIES IN NEW YORK STATE. *Michael S. Terpilak* and *Bruce L. Jorgensen. Radiation Data and Reports, Vol 15*, July 1974, pp. 375–400.

The annual quantities and types of radioactive materials released from three operating nuclear electric generating facilities, a national laboratory, and a nuclear fuels reprocessing facility are presented and discussed. The period of interest spans the years 1969 through 1972 with some additional data for those facilities operating before 1969. Release quantities have been well controlled, considering the nature and vintage of the operations.

Results of environmental surveillance relying most heavily on the activities of the New York State Department of Environmental Conservation, are presented. Observations at Indian Point Station Unit 1 and at Nuclear Fuel Services have led to the discovery of several facility-related radioisotopes in environmental media. These two facilities are of comparatively early vintage, have produced slightly larger amounts of waste materials and have been the subject of more comprehensive studies than others in the State.

Dose consequences to hypothetical individuals and to populations within 50 miles of the facilities are addressed. It should be stressed that all individual doses presented are hypothetical. Doses via the drinking water and cow's-milk-pathways are particularly conservative. In each case, these hypothetical doses are at least an order of magnitude or more greater than the known worst case. No excessive exposure levels are known to have existed. All operations have resulted in postulated exposure levels well within applicable regulations or guidelines, generally being a small percentage of these values. Population doses have been surprisingly consistent through the period of interest. They are insignificant in comparison to the dose to the population of the State from natural or medical sources.

KEYWORDS: Air, background radiation, cesium-137, fish, milk, New York, nuclear power generating plants, radioactive waste, silt, vegetation.

CALCULATED FIELD INTENSITIES NEAR A HIGH POWER UHF BROADCAST INSTALLATION. *Richard A. Tell and John C. Nelson, Radiation Data and Reports, Vol. 15*, July 1974, pp. 401–410.

A UHF transmitter site in the Washington, D.C. area, which is used cooperatively by two UHF television stations, was chosen for calculations of effective radiated power (ERP), field strength, and power density. Using the specifications for the two broadcasting stations, field strengths and power densities were calculated and presented graphically.

The calculated power densities for this broadcasting installation showed that the exposure values fall very sharply as the distance from the tower increases to about 1 mile. At distances beyond 0.5 miles, the maximum exposure values calculated were about 2.7 $\mu W/cm^2$ occurring at 0.5, 3.3, and 4.5 miles. As the height above ground at the receiving point is increased, the exposure value generally increases.

Based on the calculations for the 135 degree radial and the computed population distribution, it appears that approximately 86 000 people reside in an area within which the estimated exposure value is 1 $\mu W/cm^2$ or more.

KEYWORDS: Antenna, broadcasting station, calculations, field intensities, ultra high frequency (UHF), Washington, D.C.

ANALYSIS OF RADIATION EXPOSURES ON OR NEAR URANIUM MILL TAILINGS PILES. *Keith J. Schiager. Radiation Data and Reports, Vol. 15,* June 1974, pp. 411–425.

Potential radiation exposures from abandoned uranium mill tailings piles may be predicted in a general manner using minimal input data. If the average radium concentration in the tailings C_{Ra} is known, the external gamma exposure rate over the tailings can be estimated from: X (μR/h) $\cong$ 2.5 C_{Ra} (pCi/g). The radon emanation rate can also be estimated as: ϕ (pCi Rn/m^2-s) $\cong$ 1.6 C_{Ra} (pCi/g). The reductions of exposure rates that can be achieved by covering the tailings with earth or concrete also are discussed. Radon progeny inhalation exposures depend upon the dispersion rate of radon in the atmosphere and the time available for progeny ingrowth. Meteorological data for the site are required for making reliable predictions of inhalation exposures. It is shown, however, that contributions to the average annual outdoor radon progeny concentrations exceeding 0.003 WL are very unlikely on or near any tailings pile. The methods used to analyze potential radiation exposures are illustrated by a case study on one abandoned tailings pile.

KEYWORDS: exposure, inhalation, meteorology, radon, uranium mill tailings pile, Utah.

RADIATION DATA AND REPORTS

Volume 15, Number 8, August 1974

Radiation Data and Reports, a monthly publication of the Environmental Protection Agency, presents data and reports provided by Federal, State, and foreign governmental agencies, and other cooperating organizations. Pertinent original data and interpretive manuscripts are invited from investigators.

In August 1959, the President directed the Secretary of Health, Education, and Welfare to intensify Departmental activities in the field of radiological health. The Department was assigned responsibility within the Executive Branch for the collation, analysis, and interpretation of data on environmental radiation levels. This responsibility was delegated to the Bureau of Radiological Health, Public Health Service. Pursuant to the Reorganization Plan No. 3 of 1970, effective December 2, 1970, this responsibility was transferred to the Radiation Office of the Environmental Protection Agency which was established by this reorganization.

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DATA AND REPORTS

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U.S. ENVIRONMENTAL PROTECTION AGENCY
Russell E. Train, Administrator

Reports

Calculations of Doses, Population Doses and Potential Health Effects Due to Atmospheric Releases of Radionuclides from U.S. Nuclear Power Reactors in 1972

Office of Radiation Programs,
Environmental Protection Agency [1]

Atmospheric emissions of radionuclides during 1972 reported by operators of 14 boiling water nuclear power reactors and 2 pressurized water nuclear power reactors in the United States were analyzed to calculate resulting doses in the general offsite environment. A sector-averaged diffusion equation, using facility generated onsite annual average meteorology, was used to propagate the emissions from the release point to a radius of 80 kilometers. In 1972, 4.88 megacuries of radioactivity were released to the atmosphere from 16 reactors on 13 sites. The resulting whole body population dose was calculated to be 1649 person-rem to a population of 29.2 million people. The potential health effects induced by external radiation from nuclear power plant emissions in 1972 were less than those induced by natural background and occupational radiation exposures.

This report presents the results of calculations of doses, population doses and potential health effects due to reported atmospheric emissions of radionuclides from operating nuclear power reactors in the United States in the year 1972. The calculational techniques used in the analysis were those discussed in a previous article (*1*). Radionuclide emissions were those reported by the U.S. Atomic Energy Commission (AEC) (*2*) or the facility operator directly. In a previous article, the emissions from 10 boiling water reactors (BWR) were analyzed. This article includes the analyses of four additional BWR's and two pressurized water reactors (PWR). All data herein refer to the year 1972.

For these calculations, a yearly average wind rose and a sector averaged diffusion equation were again used to propagate the emissions. Although this technique is applicable to the analysis of long-term, chronic releases typical in BWR operations (*3*), it is not appropriate for the analysis of sporadic or intermittent release cases. Because of the generally intermittent nature of PWR emissions, the calculated doses for PWR's have substantially greater uncertainties than those due to BWR emissions. Generally, doses due to PWR emissions were probably underestimated in some sectors and overestimated in others for 1972 and are more representative of the average yearly dose rate to be expected over a long period of time if yearly emission rates remain the same and are distributed in proportion to the yearly average wind rose. This approach is unavoidable if a yearly PWR analysis is made since facilities are not presently required to report meteorological conditions prevalent during periods of atmospheric releases.

Table 1 summarizes reported emissions by radionuclide used in the dose calculations. Total emissions were somewhat higher than that re-

---

[1] The principal investigators on this project are Mr. James A. Martin, Mrs. Mary Anne Culliton and Mr. Charles Robbins of the Surveillance Branch, Field Operations Division, Office of Radiation Programs, Environmental Protection Agency, Washington, D.C.

Table 1. Noble gas radionuclide emissions from selected U.S. nuclear power reactors, 1972

Radionuclide	Quantity (kCi)													
	Big Rock Point	Dresden Unit 1	Dresden Units 2 & 3	Humboldt Bay	Genoa	Millstone Unit 1	Monticello	Nine Mile Point	Oyster Creek	Pilgrim	Quad Cities 1 and 2	Vermont Yankee	R.E. Ginna Unit 1[a]	San Onofre Unit 1[b]
Krypton:														
83m	7.1	......	......	11.0										
85m	13.0	35.0	35.0	15.0	2.2	41.4	54.0	40.3	65.5	0.18	11.7	6.0	0.045	0.04
85	.44	......	......	......	......	......	5.8	......	......	......	......	......	1.2	.34
87	36.0	102.0	75.0	59.0	2.8	77.0	103.0	75.5	149.0	3.4	19.5	10.3		
88	29.0	147.0	63.0	54.0	3.0	116.0	140.0	113.0	200.0	3.0	17.4	6.1		
89	4.8	......	......	.3										
Xenon:														
131m	.0	......	......	......	......	......	......	......	......	......	......	......	......	3.8
133m	.7	......	......	.6	......	......	......	......	......	......	......	......	......	1.14
133	21.0	70.0	83.0	17.0	1.3	189.0	114.0	65.0	151.0	3.0	31.4	11.7	10.1	13.3
135m	23.0	122.0	24.0	55.0	7.2									
135	54.0	122.0	122.0	71.0	8.6	207.0	185.0	139.0	231.0	3.2	26.9	......	......	.55
137	8.8	......	......	1.9										
138	59.0	278.0	24.0	150.0	3.9	41.9	63.4	32.5	69.7	......	25.4	.5		
Argon-41	......	......	......	......	......	......	<.17							
Nitrogen-13	2.4													
Total	259	876	426	425	29	672	665	465	866	13	132	35	11.3	19.2

[a] Specific radionuclide data from reference *2*. Total activity released was somewhat greater due to the presence of very short (< 1 minute) half-lived radionuclides. Blanks indicate activity was not reported.

[b] Pressurized water reactors chosen because their emissions in 1972 were higher than all other reactors of this type: others are boiling water reactors.

ported for 1971. Several facilities operated throughout the whole of 1972 rather than only a small fraction of the year as in 1971, and new facilities were operational in 1972. Table 2 presents a facility operating summary, the maximum calculated cloud gamma doses to hypothetical individuals at the site boundary, and the calculated population doses within 80 kilometers (50 miles) of the facilities. Overall, total population dose in the general environment increased slightly in 1972 over 1971 due to somewhat higher emissions.

An interesting comparison between offsite and onsite population doses is presented in table 3. Occupational whole body population doses from BWR's exceeded general environmental cloud gamma population doses by more than a factor of 2.

BWR's contributed predominantly to offsite cloud gamma population doses. The PWR emissions data in table 4 indicate that the Ginna and San Onofre facilities accounted for over 80 percent of all PWR emissions. Assuming the same percentage for the PWR cloud gamma population dose, the total person-rem in table 3 is also the approximate total for all nuclear power plants in operation in 1972.

Tables 5 and 6 present the reported halogen releases and calculated inhalation (thyroid) doses and ground depositions. Inhalation doses were several orders of magnitude less than cloud gamma doses. As in the previous article, ingestion (thyroid) dose via the air-foliage-cow-milk-person pathway were not calculated due to the lack of data on release heights, chemical form of the iodine emissions, and uncertainties posed by recent results of field studies (*4*) which have not corroborated available pathway parameters. (These field studies are continuing in an attempt to resolve the discrepancies.) Figure 1 (*1*) indicates that ground depositions from small releases at or near ground level may predominate at distances within 1 kilometer of a site. This is well illustrated by a comparison of the Humboldt Bay and R. E. Ginna Unit 1 data in table 6. For these two cases, a small release at low height resulted in calculated ground level concentrations comparable to that from a much larger release at a higher altitude. (For these calculations, the

Table 2. Summary of energy generated, radionuclide emissions, dose and population dose for selected U.S. nuclear power reactors, 1972

Facility	Electrical energy generated [a] (GW(e)-year)[b]	Total gaseous emissions (kCi)	Population within 80 km (thousands)	Cloud gamma population dose (person-rem)	Maximum cloud gamma dose at fencepost[c]		
					Dose (mrem)	Distance (m)	Sector
Boiling water reactors:							
Big Rock Point	0.04	259	150	8	5.0	668	WSW
Dresden Unit 1	.13	876	6 140	503	13.0	1 219	SSE
Dresden Units 2 and 3	.93	426		177	2.0	1 767	S
Humboldt Bay	.04	435	100	57	67.0	254	SE
Genoa	.03	29	[d] 123	2	.8	805	S
Millstone Unit 1	.36	672	2 480	243	8.0	492	NE
Monticello	.41	665	2 600	315	30.0	704	SSE
Nine Mile Point	.37	465	930	40	11.0	335	S
Oyster Creek	.50	866	3 520	276	37.0	400	NE
Pilgrim	.10	13	4 660	6	.19	335	SSW
Quad Cities Units 1 and 2	.44	132	600	14	1.0	896	N
Vermont Yankee	.05	35	1 100	5	3.0	277	WSW
All boiling water reactors	3.40	4 850	22 400	1 646			
Pressurized water reactors:							
R.E. Ginna Unit 1	.28	11.3	1 100	1	<.4	All	All
San Onofre Unit 1	.32	19.2	5 700	2	<.5	All	All
Two pressurized water reactors	.60	30.5	6 800	3			
All 16 reactors	4.00	4 904	29 200	1 649	— — —	— — —	— — —

[a] Assumes 0.3 electrical to thermal efficiency.
[b] 1 GW = 10^9 watts; GW(e)-yr = gigawatt (electric)-year.
[c] No credit given for building shielding or occupancy factors. Maximum dose to actual individuals was a factor of 2 to 3 lower.
[d] Within 40 km.

Table 3. Comparison of whole body population dose from gaseous emissions and occupational dose from selected reactors, United States, 1972

Facility	Whole body population dose [a] from gaseous emissions within 80 km (person-rem)	Occupational population dose [b] (person-rem)
Boiling water reactors:		
Big Rock Point	8	175
Dresden Units 1, 2, and 3	680	728
Humboldt Bay	57	254
Genoa	[c] 2	([d])
Millstone Unit 1	243	596
Monticello	315	60
Nine Mile Point	40	285
Oyster Creek	276	582
Pilgrim	6	16
Quad Cities Units 1 and 2	14	56
Vermont Yankee	5	([d])
All boiling water reactors	1 646	2 752
Pressurized water reactors:		
R. E. Ginna Unit 1	1	1 032
San Onofre Unit 1	2	257
Two pressurized water reactors	3	1 289
All 16 reactors	1 649	4 041

[a] Calculated using computer program AIREM.
[b] From testimony of Dr. Morton I. Goldman on behalf of the Consolidated Utility Group (Part 1), Nov. 9, 1973, at the AEC rulemaking hearing on effluents from light water-cooled nuclear power reactors, Docket No. RM-50-2.
[c] Within 40 km.
[d] Not available.

Table 4. PWR and HTGR releases and energy generation, 1972

Facility	Electrical energy generated (GW-yr)	Atmospheric radionuclide emissions (kCi)
Pressurized water reactors:		
San Onofre Unit 1	0.322	19.1
R. E. Ginna Unit 1	.277	11.4
Point Beach Units 1 and 2	.353	2.81
Haddam Neck	.490	.645
Indian Point Unit 1	.142	.543
Palisades	.216	.505
Robinson Unit 2	.50	.257
Yankee	.0733	.0183
Maine Yankee	.0528	.002
Surry Unit 1	.0421	<.001
Total	2.47	35.28
High temperature gas reactor:		
Peach Bottom Unit 1	.012	.058

elemental iodine (I_2) chemical form was assumed for *all* iodine releases; this may not be the case (*4*).)

A brief explanation for the difference in the magnitude of BWR and PWR emissions is in

Table 5. Halogen releases from selected U.S. nuclear power reactors, 1972

Facility	Effective release height [a] (m)	Quantity (Ci)		
		Iodine-131	Iodine-133	Iodine-135
Boiling water reactors:				
Big Rock Point	100	0.122	0.017	(b)
Dresden Unit 1	120	2.5	5.0	5.0
Dresden Units 2 and 3	200	5.0	10.0	10.0
Humboldt Bay	75	.4	1.7	(b)
Genoa	120	.693	.469	.012
Millstone Unit 1	150	1.23	(b)	(b)
Monticello	100	.576	1.16	2.26
Nine Mile Point	150	.893	.515	.279
Oyster Creek	150	6.26	7.01	5.82
Pilgrim	100	<.0266	.915	(b)
Quad Cities Units 1 and 2	200	.730	.603	.0703
Vermont Yankee	150	.171	.160	(b)
All boiling water reactors		18.6	27.61	23.4
Pressurized water reactors:				
R.E. Ginna Unit 1	10	.0335	.0015	(b)
San Onofre Unit 1	50	4.42×10^{-4}	(b)	(b)
Two pressurized water reactors		.0335	.0015	(b)
All 16 reactors		18.6	27.61	23.4

[a] Includes plume rise per reference *1*, except Quad Cities plum rise = 105 m and plume rise for Ginna and San Onofre = 0. Halogens presumed to be emitted from the stack at the effective release height.
[b] Emissions not reported.

order. The lower off-gas volumes which result from a typical PWR design permits these gases to be stored so that the shorter-lived radionuclides can decay. For BWR's, inplant holdup times are typically 1 hour or less. For PWR's, decay periods up to several months can be achieved under optimal conditions. This greater decay time contributes to the difference between PWR and BWR release magnitudes for plants with similar generating histories. A proposed regulation promulgated by the AEC (*5*) will require reductions in BWR gaseous emissions either by the installation of additional holdup capacity or by removal of the gaseous wastes. Thus, for future operation, doses from BWR releases may be expected to be substantially reduced. This may begin to occur as early as 1974.

The risk values given in the BEIR Report (*6*) were again used to estimate the number of potential health effects from external gamma radiation likely to occur in the populations residing within 80 km of operating nuclear power sta-

Table 6. Calculated inhalation (thyroid) doses and iodine-131 depositions, 1972

Facility	Heff (m)	Iodine-131 released (Ci)	Adult inhalation (thyroid) population dose [a] within 80 km [a] (person-rem)	Maximum saturated ground activity [b]		
				(pCi/m²)	Distance (km)	Sector
Boiling water reactors:						
Big Rock Point	100	0.122	<0.005	1	1.2	ENE & SSW
Dresden Unit 1	120	2.5	1.34	20	2.4	SSE & NW
Dresden Units 2 and 3	200	5.0	1.94	15	2.4	SSE & NW
Humboldt Bay	75	.4	.03	37	.6	N
Genoa	150	.69	.04	10	2.4	N
Millstone Unit 1	150	1.23	.27	6	2.4	ENE
Monticello	100	.58	.22	11	1.2	SSE
Nine Mile Point	150	.89	.04	22	1.2	N
Oyster Creek	150	6.26	1.48	46	1.2	N
Pilgrim	100	<.03	0	<.5	All	All
Quad Cities Units 1 and 2	200	.73	.05	≤1	2.4	All
Vermont Yankee	150	.17	.03	4	.8	SSE
Pressurized water reactors:						
R.E.Ginna Unit 1	10	.0335	<.005	61	.5	NE
San Onofre Unit 1	50	4.4×10^{-4}	<.005	<0.01	All distances	
Total		18.6				

[a] Adult inhalation (thyroid) dose is less than 10 μrem in all cases.
[b] Assumes 1 cm/s deposition velocity, stack release, dry deposition only.

tions in 1972. Three sources of radiation were considered: natural background radiation, the external gamma radiation from atmospheric radionuclide reactor emissions, and occupational exposures. Potential health effects from radiation include fatal cancers, nonfatal cancers, and genetic effects in the approximate ratios 2:2:3, respectively. Somatic effects are assumed to occur within 30 years or so of exposure; genetic effects extend over several generations. The calculated health effects, based upon a risk factor of 7×10^{-4} health effects per person-rem (*7*) are presented in table 7. Uncertainties associated with calculations in this report are discussed in the previous article (*1*).

In summary, atmospheric emissions of radionuclides from 16 nuclear power facilities on 13 sites were analyzed to calculate resulting environmental doses for 1972. These facilities generated a total of 4000 megawatt-years of electrical energy during the year. The cloud gamma population doses to the populations within 80 km (50 miles) of these facilities, due to atmospheric emissions of 4904 kilocuries of radionuclides totaled 1649 person-rem in a population of 29.2 million. For the nuclear power industry as a whole, extrapolation of these data would indicate a total of about 1700 person-rem offsite cloud gamma population doses resulting from the production of 5880 megawatt-years of electrical energy by nuclear

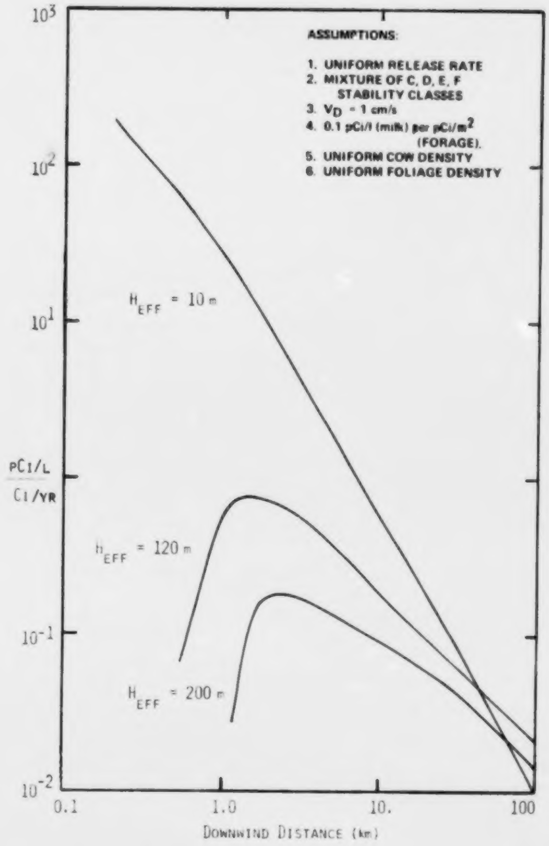

Figure 1. Iodine-131 concentration in milk in a typical high frequency sector (per curie released)

Table 7. Calculated potential health effects, 1972

Facility	Population [a] (millions)	Electrical energy produced (GW(e)-yr)	Noble gas emissions (kCi)	Potential health effects		
				Natural [b] background	Cloud gamma	Occupational
Big Rock Point	0.15	0.04	235	9	0.0056	0.12
Dresden Units 1, 2 and 3	6.2	1.06	1 302	370	.48	.51
Humboldt Bay	.1	.04	435	5	.04	.18
Genoa (La Crosse)	.12	.03	29	8	.0014	--------
Millstone Unit 1	2.5	.36	672	160	.17	.42
Monticello	2.6	.41	665	140	.22	.042
Nine Mile Point	.9	.37	465	65	.028	.20
Oyster Creek	3.5	.50	866	160	.19	.41
Pilgrim Unit 1	4.7	.10	13	280	.0042	.011
Quad Cities Units 1 and 2	.6	.44	132	37	.11	.04
Vermont Yankee	1.1	.05	35	70	.0035	--------
R.E. Ginna Unit 1	1.2	.28	11.4	70	.0007	.72
San Onofre Unit 1	5.7	.32	19.1	290	.0014	.18

[a] Estimated populations within 80 km (50 miles) of the sites (40 km for Genoa).
[b] Natural background dose rate from reference *8*,

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power facilities in 1972. Potential health effects induced by external radiation from nuclear power operations in 1972 were predominantly due to occupational exposures. Extrapolation of the population statistics for the sites considered, to include all sites, would indicate that between one-fifth and one-quarter of the U.S. population lived within 80 km (50 miles) of an operating nuclear power plant in 1972.

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Radioactivity in Brazilian Mineral Waters[1]

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G. Zundel,[4] and T. L. Cullen[5]

Samples of mineral waters from various parts of Brazil were analyzed for their radium content. Radium-226 activity ranged from nondetectable to 94.1 pCi/liter, and radium-228 ranged from nondetectable to 152 pCi/liter.

In some countries of the world, bottled mineral waters are widely consumed for their health giving qualities. Among these qualities, at times, is the radioactive content. The label on Brazilian mineral waters normally gives the content in Mache Units.[6] It is of interest to note these waters as examples of the natural radioactive contamination of the environment.

These waters have been analyzed in the past (*1,2*) but the measurements have generally been based on the radon contained in the water. Advances in the radiochemical techniques in the past decade, however, justify a repetition of these measurements.

The samples were collected in plastic bottles at the source and shipped to Rio de Janeiro. Basically, the method of A. S. Goldin was then used (*3*). The sulphates of barium and radium are precipitated and collected onto a membrane filter after purification. The alpha activity is then counted using a plastic phosphor and phototube.

The activity is measured 30 days after precipitation and drying, and again after 60 days. The two measurements enable us to separate out the activities due to the two isotopes, radium-226 and radium-228. The data are presented in table 1.

Some of the rather active waters, from Caxambú (figure 1), were also bought in the commercial bottles and measured. It seems that an ion-exchange process removes the radium from the water and fixes it in the glass of the bottle before the water gets to the customer.

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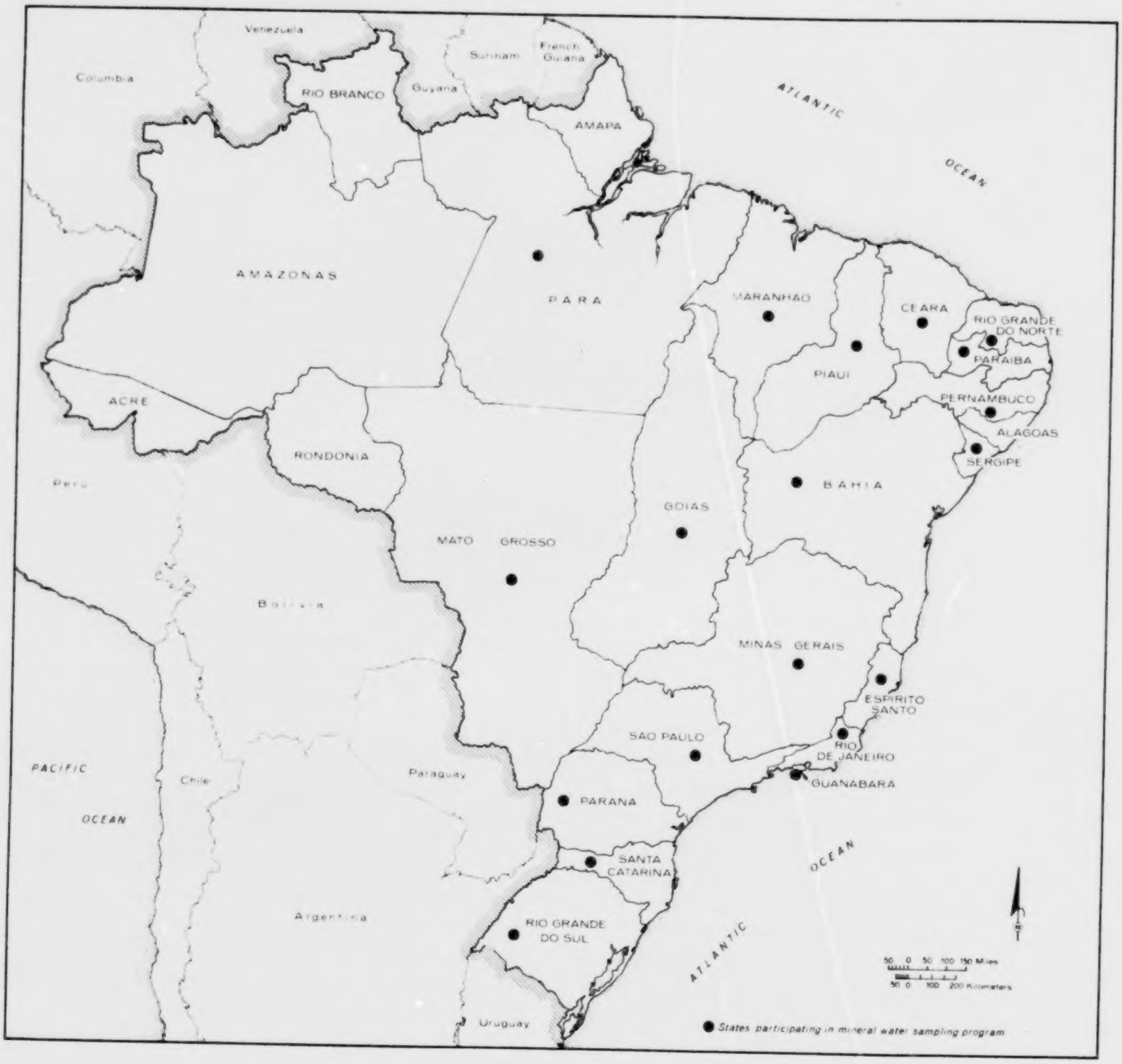
[6] A Mache Unit corresponds to the measurement of the saturation current produced by emanation (expressed in absolute electrostatic units multiplied by 1000 occurring over a period of 1 hour from 1 liter of water. A Mache Unit is approximately equal to 0.364 nCi.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RIO GRANDE DO NORTE
PIAUI
PARAIBA
PERNAMBUCO
ALAGOAS
SERGIPE
ACRE
RONDONIA
Peru
BAHIA
GOIAS
MATO GROSSO
Bolivia
MINAS GERAIS
ESPIRITO SANTO
SAO PAULO
RIO DE JANEIRO
GUANABARA
PACIFIC
OCEAN
Chile
Paraguay
PARANA
SANTA CATARINA
OCEAN
ATLANTIC
Argentina
RIO GRANDE DO SUL
Uruguay
50 0 50 100 150 Miles
50 0 100 200 Kilometers
● States participating in mineral water sampling program

Figure 1. Radioactivity in Brazilian mineral waters

Table 1. Radioactivity in Brazilian mineral waters

State, municipality	Source	Radium 226 (pCi/liter)	Radium-228 (pCi/liter)
Bahia:			
Caldas de Cipó	Caldas de Cipó	10.27	8.77
Camacarí	Dias D'Avila	.40	3.00
Cipó	Jórro	.28	.63
Coraçao de Maria	San Juliano	.50	1.16
Itaparica (Ilha de Itaparica)	Bica	1.95	1.87
Itapicurú	Itapicurú	.24	.49
Ceará:			
Fortaleza	Sao Geraldo	2.84	8.85
	Santa Ines	1.57	1.69
	Verdes Mares	25.91	15.03
Espírito Santo:			
Alegre	Conceiçao	ND	ND
Guaraparí	Mineral	.02	ND
Serra	Mineral	.10	1.15
Goias:			
Caldas Novas	Baths	.23	1.42
	Well near baths	.25	1.12
	Pool	.22	.58
	Poço do Padre	.23	.28
Caldas de Pirapitinga	Lake	.19	.21
	Lake drainage	.22	.23
	Well near river Pirapí	.18	.32
Caldas Velhas	Poço do Governador	.80	.91
	Well I	.91	1.65
	Well II	.99	.25
Pousada do Rio Quente	Ponte Japonesa:		
	Spring I	.35	1.03
	Spring II	.13	.28
	Spring III	.53	1.30
	Well no 4	.97	.56
Goiania, Chácara São José	Vindobona	ND	.25
Itapirapua, Fazenda			
Sao Joao	Sulfurosa fount	ND	.20
	Sulfurosa baths	.12	.46
Guanabara:			
Rio de Janeiro	Federal	.11	ND
	Nazaré	.18	ND
	Rica	.99	1.86
	Fontana	.11	ND
	Santa Cruz	ND	ND
Maranhao:			
Caxias	Veneza	.03	.38
Sao Luiz	Jaguarema	9.76	13.03
Mato Grosso:			
Barra do Garças	Hot spring	.20	ND
	Sao Sebastiao	.23	ND
General Carneiro	Hot spring	.16	.67
Palmeiras		.22	.38
Minas Gerais:			
Além Paraíba, paper factory	Well, 70 m deep	.12	
Além Paraíba	Fazenda Bom Retiro	.09	
Andradas	City supply	.07	
Araxá	Dona Beja	2.20	
Baependí	City supply	.02	
Belo Horizonte	City supply	.02	
Bicas	City supply	.03	
Caldas	City supply	.03	
Cambuquira	Marimbeiro I	1.66	
	Marimbeiro II	1.80	
	Marimbeiro III	1.57	
	Magnesiana	1.66	
	Gasosa a	1.91	
	Gasosa b	1.43	8.2
	Roxo Rodrigues	1.03	13.2
	Ferruginosa	5.02	10.4
	Souza Lima	3.33	10.1
Catagunzes	City supply	.03	
Caxambú	Mayrink I	1.58	3.8
	Mayrink II	2.53	18.2
	Mayrink III	2.08	4.2
	Viotti	2.21	2.7
	Dom Pedro II	3.91	7.0
	Dona Leopoldina	3.48	2.9
	Duque de Saxe	5.92	16.2
	Dona Isabel	18.7	5.1
	Conde d'Eu	18.9	7.3
	Beleza	87.8	118.8
	Venancio	94.1	102.8
	Nova	91.3	151.6
	Nascente Riacho Bengo	.05	
	Açude do Parque	ND	
Conceiçao do Rio Verde	Rio Verde	.14	
Contendas	Ferruginosa	.74	
	Magnesiana	1.09	
	Alcalina	.33	
	Gasosa forte	1.26	
	Bica do Pasto	.19	
	V. Marina	.22	
	Riacho do Parque	.05	

Table 1. Radioactivity in Brazilian mineral waters—continued

State, municipality	Source	Radium-226 (pCi/liter)	Radium-228 (pCi/liter)
Contendas	Well no 1 (16 m deep)	0.16	
	Well no 2 (6 m deep)	.12	
	Well no 3 (10 m deep)	.16	
	Well no 4 (18 m deep)	.13	
	Well no 5 (5 m deep)	.15	
	Well no 6 (5 m deep)	.09	
	Well no 7 (15 m deep)	.24	
	Well no 8 (7 m deep)	.09	
Dona Euzébia	Hélios	.02	
Ipuiuna	City supply	ND	
Itajubá	City supply	.02	
Jacutinga	São Clemente	.05	
Juiz de Fora	City supply	.03	
Lambarí	City supply	.03	
	No 1	3.02	ND
	No 2	2.86	ND
	No 3	3.25	
	No 4	1.28	
Leopoldina	City supply	.07	
Mar de Espanha	City supply	.66	
Montes Claros	City supply	.03	
Monte Sião	Natural	.05	
Montezuma	Bath I	.23	
	Bath II	.60	
Passo Quatro	City supply	.02	
	Julio Reanier	.06	
	Padre Manoel	.26	
Patrocínio	City supply	.02	
Piquete	City supply	.02	
Pocinhos do Rio Verde	Rio Verde	ND	
	São José	.02	
	Samaritana	.02	
	Amorosa	.35	
Poços de Caldas	City supply	ND	
	Sinhasinha	.06	
	Macacos	ND	
	Amores	ND	
	Santana	ND	
	Frayha	ND	
	15 de Novembro	ND	
	N.S. da Saúde	.08	
	Pedro Botelho	.09	
	Vivaldi	.17	
	Sto. Antonio	.08	
Route Rio-Bahia km 72	Well (40 m deep)	1.61	4.5
Salvaterra	Salvaterra	ND	
Samaritana	São Francisco	.17	1.12
Santa Rita de Sapucaí	City supply	.05	
São Lourenço	City supply	.11	
	Gasosa	.68	
	Magnesiana	1.91	
	Ferroginosa	6.47	5.0
	Alcalina	5.48	24.4
	Alcalina-Carbo-Sulphorous	9.32	18.4
	Alcalina, Vichy	11.18	25.2
São Luiz	Natural	.03	
	Água Vita	.09	
Sarandí	Sarandí	.33	1.2
Tebas	Thebana	ND	
Thermópolis	Baths	.16	
Tiradentes, Hidrominas	Pool	.35	.69
	Well, in field	.03	
	City supply	.09	
Pará:			
Belém	N.S. dé Nazaré	.26	1.80
Salinas	Caranã	3.16	4.86
Paraíba:			
São Gonçalo	Brejo das Freiras	.36	.69
Paraná:			
Araucária	Prata de Casa	.12	ND
Bandeirantes	Yara	.02	ND
Campo Largo	Ouro Fino	.11	ND
Castro	Água Quente	.26	ND
	Paraná	.06	.42
Cornélio Procópio	Água Quente	.32	ND
Curitiba	City supply	ND	ND
	Aú	ND	ND
Fazenda Mendes	Jacú	ND	ND
Guarapuava	Santa Clara	ND	ND
	N. S. de Lourdes	ND	ND
	São Francisco	ND	ND
	Boa Vista	.05	ND
Jaguariava	Lambedor	ND	ND
Londrina	City supply	ND	ND
	Lon—Rita	.02	ND
Ponta Grossa	City supply	.04	.37
Pernambuco:			
Fazenda Nova		1.15	3.26
João Alfredo	Salgadinho	3.59	3.46
Quipapá	São Benedito	.06	.12
Recife	Santa Clara	.32	3.26

Table 1. Radioactivity in Brazilian mineral waters—continued

State, municipality	Source	Radium-226 (pCi/liter)	Radium-228 (pCi/liter)
Piaui:			
Cidade Jardim	Soropo	1.42	ND
Teresina	Agua Regina, Boqueirao	.62	
	York	4.13	1.67
Rio de Janeiro:			
Barra do Piraí	Ibitira	.09	ND
Campos	Bellieny	.04	
Itaboraí	Ferma	.09	
	Itaboraí	.03	
Itaperuna	Soledade, Sulphurous	.13	
	Soledade, Carbonated	.06	
	Cubatao	.03	
	Avahy	.07	
	Raposo	.14	
Magé	Santa Rita	.09	
Nova Friburgo	Boa Esperança	ND	
Nova Iguaçú	Ambaí	.09	
	Corcovado	.05	
	Sao Francisco de Paulo	.10	
Paraíba do Sul	City supply	.04	
Passa Tres	N. S. das Graças	.08	
Petrópolis	Petrópolis	.04	
	Castelliania	.35	
Salutaris	Maria Rita	.46	1.17
	Nilo Peçanha	.88	1.69
Sao Goncalo	Sao Gonçalo	.40	
Sto. Antônio de Pádua	Farol	.05	
	Iodetada	.04	
Teresópolis	Teresópolis	.04	
Rio Grande do Norte:			
Extremoz	Santos Reis, Portinho	.72	1.05
Mossoró	Costa e Silva	4.88	ND
	Costa Calvacanti	6.16	.21
	Moacyr Vasconcelos	4.84	ND
	Paulo Godoy	1.37	ND
Rio Grande do Sul:			
Alegrete	Pampa	ND	ND
Frederico Westphalen	Prado	2.83	.22
Ijuí	Itaí	.32	.07
	Sulina	.60	.05
	Oswaldo Cruz	ND	.50
Pelotas	Serrana	ND	.15
Porto Alegre	Charrua	ND	.28
	Minuano	.57	.15
Santo Angelo	Nascente	3.74	.21
	Santa Tereza	ND	ND
Sao Leopoldo	Sempre Viva	.20	ND
Santa Catarina:			
Armazém	Santa Teresinha	.04	ND
Caldas de Cubatao	Santa Catarina	.18	.63
Chapecó	Chapecó	.45	ND
Florianópolis	City supply	ND	ND
Gravatá	Gravatal	.16	.62
Guarda—Tubarao	S. Anjo da Guarda	3.20	ND
	Rio Pouso	.35	ND
Palmitos	Ilha Redona	2.20	.50
Route BR-2, km 330	Sulfurosa	.14	.81
Santo Amaro	Caldas de Imperatriz	.08	ND
Urussanga	Sulfurosa, S. Pedro	3.61	5.25
	Thermal, S. Pedro	5.05	2.03
Sao Paulo:			
Aguas da Prata	Paiol	.04	
	Vilela	29.96	ND
	Vitória	.60	
	Nova	.36	
	Antiga	.16	
Amparo	Bocaina	1.07	4.84
Baurú	Santa Teresinha	.50	1.7
Bofete	Bofete	.76	
Campos do Jordao	Pinheiral	.05	
	Marisa	.21	
Cotia	Pluma	.20	
Embú	Jesuitas	.18	
Glicério	Sao Jorge	.02	
Indaiatuba	Santa Elisa	.27	
	Itaici	.57	
Jacanga	Pocinho do Quilombo	.05	
Lindoia	Sao Benedito	.28	
	Tamoio	.41	
	Lindalia	.49	
Mairipora	Paulistinha	.07	
Mogi das Cruzes	Mogiana	.15	
	Aurea	.18	
Santos	Vila Mathias	.11	
	Drinking	.08	
	Biquinha	.10	
Ribeirao Pires	Serrania	.08	
	Pilar	.05	
Sao Paulo	Drinking	.08	
	Fontalis	.12	
	Gioconda	.03	
	Jaraguá 1	.33	

Table 1. Radioactivity in Brazilian mineral waters—continued

State, municipality	Source	Radium-226 (pCi/liter)	Radium-228 (pCi/liter)
Sao Paulo	Jaraguá 2	.09	
	Lausane	.09	
	Sao Pedro	.16	
	N. S. Lourdes	.10	
	Petrópolis	.09	
Sao Pedro	Almeida Sales	.27	
	Gioconda	.73	
	Juventude	.57	
Serra Negra	Rosário	.07	
	Sto. Agostinho	.09	
Sertaozinho	Palmital	.03	
	Sertaneja	ND	
Socorro	Pompeia	.08	
Taubate	Imaculada Conceiçao	.14	
	Sao Francisco	.39	

ND, nondetectable.

SECTION I. MILK AND FOOD

Milk Surveillance, March 1974

Although milk is only one of the sources of dietary intake of environmental radioactivity, it is the food item that is most useful as an indicator of the general population's intake of radionuclide contaminants resulting from environmental releases. Fresh milk is consumed by a large segment of the population and contains several of the biologically important radionuclides that may be released to the environment from nuclear activities. In addition, milk is produced and consumed on a regular basis, is convenient to handle and analyze, and samples representative of general population consumption readily can be obtained. Therefore, milk sampling networks have been found to be an effective mechanism for obtaining information on current radionuclide concentrations and long-term trends. From such information, public health agencies can determine the need for further investigation or corrective public health action.

The Pasteurized Milk Network (PMN) sponsored by the Office of Radiation Programs, Environmental Protection Agency, and the Office of Food Sanitation, Food and Drug Administration, Public Health Service, consists of 65 sampling stations: 63 located in the United States, one in Puerto Rico, and one in the Canal Zone. Many of the State health departments also conduct local milk surveillance programs which provide more comprehensive coverage within the individual State. Data from 15 of these State networks are reported routinely in *Radiation Data and Reports.* Additional networks for the routine surveillance of radioactivity in milk in the Western Hemisphere and their sponsoring organizations are:

Pan American Milk Sampling Program (Pan American Health Organization and U.S. Environmental Protection Agency)—5 sampling stations

Canadian Milk Network (Radiation Protection Division, Canadian Department of National Health and Welfare)—16 sampling stations.

The sampling locations that make up the networks reporting presently in *Radiation Data and Reports* are shown in figure 1. Based on the similar purpose for these sampling activities, the present format integrates the complementary data that are routinely obtained by these several milk networks.

Radionuclide and element coverage

Considerable experience has established that relatively few of the many radionuclides that are formed as a result of nuclear fission become incorporated in milk (*1*). Most of the possible radiocontaminants are eliminated by the selective metabolism of the cow, which restricts gastrointestinal uptake and secretion into the milk. The five fission-product radionuclides which commonly occur in milk are strontium-89, strontium-90, iodine-131, cesium-137, and barium-140. A sixth radionuclide, potassium-40, occurs naturally in 0.0118 percent (*2*) abundance of the element potassium, resulting in a specific activity for potassium-40 of 830 pCi/g total potassium.

Two stable elements which are found in milk, calcium and potassium, have been used as a means for assessing the biological behavior

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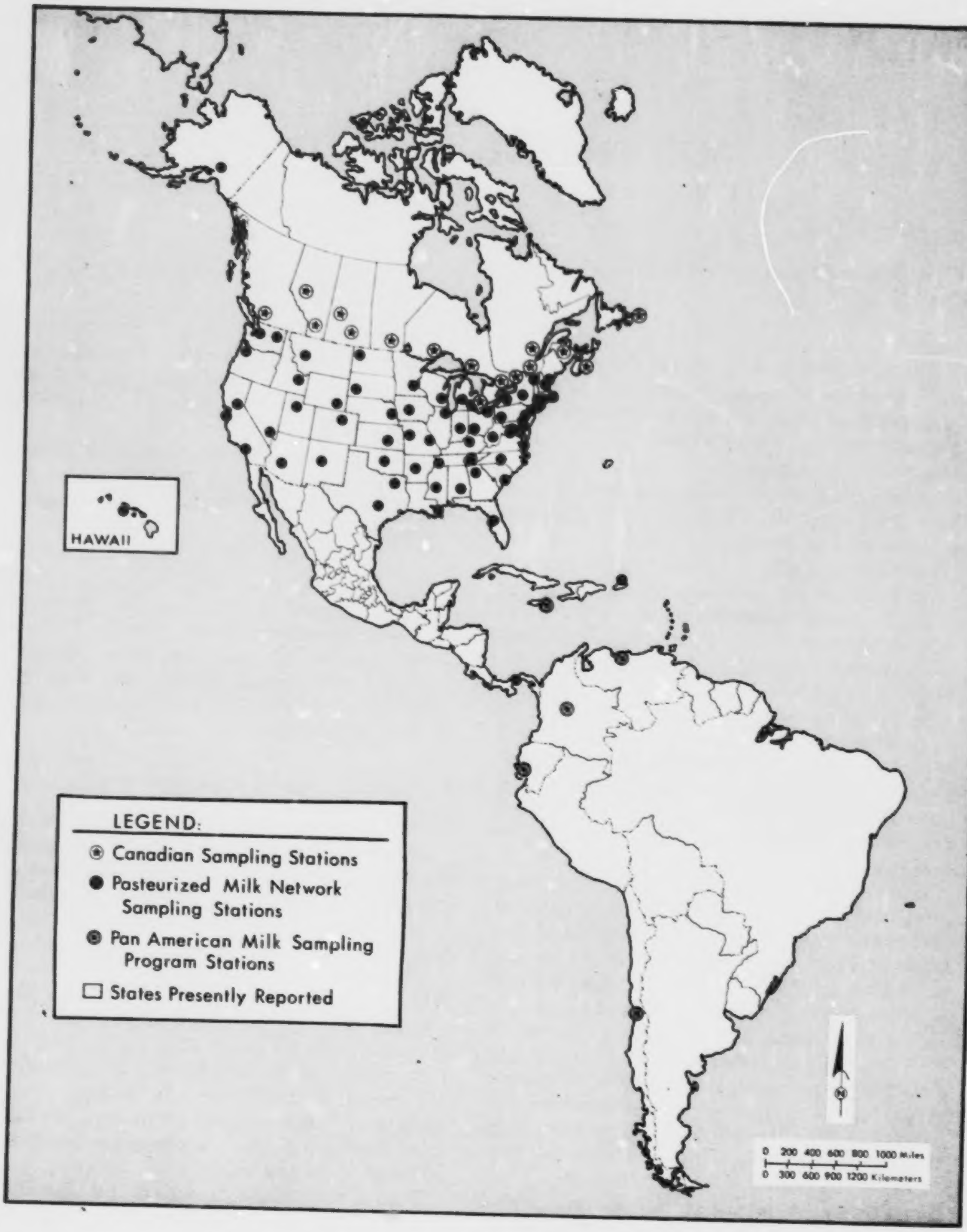
HAWAII
LEGEND:
⊛ Canadian Sampling Stations
● Pasteurized Milk Network Sampling Stations
◉ Pan American Milk Sampling Program Stations
☐ States Presently Reported
N
0 200 400 600 800 1000 Miles
0 300 600 900 1200 Kilometers

Figure 1. Milk sampling networks in the Western Hemisphere

of metabolically similar radionuclides (radiostrontium and radiocesium, respectively). The contents of both calcium and potassium in milk have been measured extensively and are relatively constant. Appropriate values and their variations, expressed in terms of 2 standard deviations (2σ), for these elements are 1.16 ± 0.08 g/liter for calcium and 1.51 ± 0.21 g/liter for potassium. These figures are averages of data from the PMN for May 1963–March 1966 (*3*) and are used for general radiation calculations.

Accuracy of data from various milk networks

In order to combine data from the international, national, and State networks considered in this report, first it was necessary to determine the accuracy with which each laboratory is making its determinations and the agreement of the measurements among the laboratories. The Analytical Quality Control Service of the Research and Development Programs conducts periodic studies to assess the accuracy of determinations of radionuclides in milk performed by interested radiochemical laboratories. The generalized procedure for making such a study has been previously outlined (*4*).

The most recent study was conducted during June 1972 with 37 laboratories participating in an experiment on a milk sample containing known concentrations of iodine-131, cesium-137, strontium-89, and strontium-90 (*5*). Of the 18 laboratories producing data for the networks reported in *Radiation Data and Reports*, 14 participated in the study.

The accuracy results of this study for these 14 laboratories are shown in table 1. The accuracy of the cesium-137 measurements continues to be excellent as in previous experiments. However, both the accuracy and precision need to be improved for iodine-131, strontium-89, and strontium-90 which could probably be accomplished through recalibration.

Development of a common reporting basis

Since the various networks collect and analyze samples differently, a complete understanding of several parameters is useful for interpreting the data. Therefore, the various milk surveillance networks that report regularly were surveyed for information on analytical methods, sampling and analysis fequencies, and estimated analytical errors associated with the data.

In general, radiostrontium is collected by an ion-exchange technique and determined by beta-particle counting in low-background detectors, and the gamma-ray emitters (potassium-40, iodine-131, cesium-137, and barium-140) are determined by gamma-ray spectroscopy of whole milk. Each laboratory has its own modifications and refinements of these basic methodologies.

Many networks collect and analyze samples on a monthly basis. Some collect samples more frequently but composite the several samples for one analysis, while others carry out their analyses more often than once a month. Many networks are analyzing composite samples on

Table 1. Distribution of mean results, quality control experiment

Isotope and known concentration	Number of laboratories in each category				Experimental 2σ error (pCi/liter)
	Acceptable [a]	Warning level [b]	Unacceptable [c]	Total	
Iodine-131: (96 or 99 pCi/liter)	7 (58%)	1 (8%)	4 (33%)	12	6
(438 or 484 pCi/liter)	11 (85%)	0	2 (15%)	13	25 or 28
Cesium-137: (53 or 54 pCi/liter)	11 (92%)	0	1 (8%)	12	6
(295 or 303 pCi/liter)	11 (85%)	2 (15%)	0	13	17
Strontium-89: (29 or 30 pCi/liter)	9 (82%)	0	2 (18%)	11	6
(197 or 201 pCi/liter)	3 (33%)	1 (11%)	5 (56%)	9	11 or 12
Strontium-90: (32.1 or 32.4 pCi/liter)	4 (33%)	4 (33%)	4 (33%)	12	1.9
(150.5 or 151.2 pCi/liter)	6 (55%)	0	5 (45%)	11	8.7

[a] Measured concentration to or within 2σ of the known concentration.
[b] Measured concentration outside 2σ and equal to or within 3σ of the known concentration.
[c] Measured concentration outside 3σ of the known concentration.

a quarterly basis for certain nuclides. The frequency of collection and analysis varies not only among the networks but also at different stations within some of the networks. In addition, the frequency of collection and analysis is a function of current environmental levels. The number of samples analyzed at a particular sampling station under current conditions is reflected in the data presentation. Current levels for strontium-90 and cesium-137 are relatively stable over short periods of time, and sampling frequency is not critical. For the short-lived radionuclides, particularly iodine-131, the frequency of analysis is critical and generally is increased at the first measurement or recognition of a new influx of this radionuclide.

The data in table 2 show whether raw or pasteurized milk was collected. An analysis (*6*) of raw and pasteurized milk samples collected during January 1964 to June 1966 indicated that for relatively similar milkshed or sampling areas, the differences in concentration of radionuclides in raw and pasteurized milk are not statistically significant (*6*). Particular attention was paid to strontium-90 and cesium-137 in that analysis.

Practical reporting levels were developed by the participating networks, most often based on 2-standard-deviation counting errors or 2-standard-deviation total analytical errors from replicate analyses (*3*). The practical reporting level reflects analytical factors other than statistical radioactivity counting variations and will be used as a practical basis for reporting data.

The following practical reporting levels have been selected for use by all networks whose practical reporting levels were given as equal to or less than the given value.

Radionuclide	Practical reporting level (pCi/liter)
Strontium-89	5
Strontium-90	2
Iodine-131	10
Cesium-137	10
Barium-140	10

Some of the networks gave practical reporting levels greater than those above. In these cases, the larger value is used so that only data considered by the network as meaningful will be presented. The practical reporting levels apply to the handling of individual sample determinations. The treatment of measurements equal to or below those practical reporting levels for calculation purposes, particularly in calculating monthly averages, is discussed in the data presentation.

Analytical error of precision expressed as pCi/liter or percent in a given concentration range also has been reported by the networks (*3*). The precision errors reported for each of the radionuclides fall in the following ranges:

Radionuclide	Analytical errors of precision (2 standard deviations)
Strontium-89	1–5 pCi/liter for levels <50 pCi/liter; 5–10% for levels ≧50 pCi/liter;
Strontium-90	1–2 pCi/liter for levels <20 pCi/liter; 4–10% for levels ≧20 pCi/liter;
Iodine-131 Cesium-137 Barium-140	4–10 pCi/liter for levels <100 pCi/liter; 4–10% for levels ≧100 pCi/liter.

For iodine-131, cesium-137, and barium-140, there is one exception for these precision error ranges: 25 pCi/liter at levels <100 pCi/liter for Colorado. This is reflected in the practical reporting level for the Colorado milk network.

Federal Radiation Council guidance applicable to milk surveillance

In order to place the United States data on radioactivity in milk in perspective, a summary of the guidance provided by the Federal Radiation Council for specific environmental conditions was presented in the February 1973 issue of *Radiation Data and Reports*.

Data reporting format

Table 2 presents the integrated results of the international, national, and State networks discussed earlier. Column 1 lists all the stations which are reported routinely in *Radiation Data and Reports*. The relationship between the PMN

Table 2. Concentrations of radionuclides in milk for March 1974 and 12-month period, April 1973 through March 1974

Sampling location		Type of sample [a]	Radionuclide concentration (pCi/liter)			
			Strontium-90		Cesium-137	
			Monthly average [b]	12-month average	Monthly average [b]	12-month average
UNITED STATES:						
Ala:	Montgomery [c]	P	NA	4	0	3
Alaska:	Palmer [c]	P	NA	4	0	1
Ariz:	Phoenix [c]	P	NA	0	0	0
Ark:	Little Rock [c]	P	NA	11	0	1
Calif:	Los Angeles [c]	P	NA	0	0	0
	Sacramento [c]	P	NA	1	11	1
	San Francisco [c]	P	NA	0	0	0
	Del Norte	P	0	10	0	4
	Fresno	P	0	1	0	1
	Humboldt	P	3	2	0	1
	Los Angeles	P	3	1	0	1
	Mendocino	P	2	2	0	1
	Sacramento	P	0	2	0	3
	San Diego	P	0	1	0	1
	Santa Clara	P	0	1	0	2
	Shasta	P	2	2	0	2
	Sonoma	P	2	2	0	3
Colo:	Denver [c]	P	NA	3	0	0
	East	R	NS	NA	NS	23
	Northeast	R	NS	NA	NS	0
	Northwest	R	NS	NA	NS	3
	South Central	R	NS	NS	NS	NS
	Southeast	R	NS	NA	NS	0
	Southwest	R	NS	NA	NS	0
	West	R	NS	NA	NS	0
Conn:	Hartford [c]	P	NA	4	0	2
	Central	P	NA		NA	
Del:	Wilmington [c]	P	NA	6	0	1
D.C:	Washington [c]	P	NA	3	0	0
Fla:	Tampa [c]	P	NA	4	28	25
	Central	R	5	5	59	29
	North	R	6	6	0	14
	Northeast	R	6	6	20	28
	Southeast	R	5	5	31	48
	Tampa Bay area	P	5	5	21	27
	West	R	8	8	0	8
Ga:	Atlanta [c]	P	NA	4	0	2
Hawaii:	Honolulu [c]	P	NA	0	0	0
Idaho:	Idaho Falls [c]	P	NA	3	0	0
Ill:	Chicago [c]	P	NA	5	0	0
Ind:	Indianapolis [c]	P	NA	5	13	3
	Central	P	4	5	0	5
	Northeast	P	5	5	0	10
	Northwest	P	7	7	0	8
	Southeast	P	6	6	0	7
	Southwest	P	9	7	0	5
Iowa:	Des Moines [c]	P	NA	4	0	0
	Des Moines	R	4	5	0	0
	Iowa City	R	6	5	0	0
	LeMars	R	3	4	0	0
	Little Cedar	P	7	6	0	0
Kans:	Wichita [c]	P	NA	5	0	1
	Coffeyville	P	6	6	0	7
	Dodge City	P	4	4	0	6
	Falls City, Nebr	R	3	6	0	8
	Hays	P	5	6	0	5
	Kansas City	P	6	5	0	5
	Topeka	P	5	6	10	6
Ky:	Louisville [c]	P	NA	5	0	1
La:	New Orleans [c]	P	NA	6	13	2
Maine:	Portland [c]	P	NA	4	14	13
Md:	Baltimore [c]	P	NA	6	0	3
Mass:	Boston [c]	P	NA	7	0	8
Mich:	Detroit [c]	P	NA	6	13	4
	Grand Rapids [c]	P	NA	7	0	1
	Bay City	P	11	11	0 (2)	2
	Charlevoix	P	8	9	0 (5)	2
	Detroit	P	6	8	0	0
	Grand Rapids	P	17	13	17	5
	Lansing	P	11	12	0 (2)	3
	Marquette	P	15	12	0	7
	Monroe	P	8	12	0 (2)	1
	South Haven	P	10	14	0 (4)	3
Minn:	Minneapolis [c]	P	NA	7	0	1
	Bemidji	P	NS	6	NS	0
	Duluth	P	12	16	0	16
	Fergus Falls	P	5	6	0	0
	Little Falls	P	12	16	0	25
	Mankato	P	5	5	0	0
	Marshall	P	NS	3	NS	0

See footnotes at end of table.

Table 2. Concentrations of radionuclides in milk for March 1974 and 12-month period, April 1973 through March 1974—continued

Sampling location		Type of sample [a]	Radionuclide concentration (pCi/liter)			
			Strontium-90		Cesium-137	
			Monthly average [b]	12-month average	Monthly average [b]	12-month average
Minn:	Minneapolis	P	8	9	0	0
	Rochester	P	5	6	0	0
Miss:	Jackson [c]	P	NA	8	0	5
Mo:	Kansas City [c]	P	NA	4	0	0
	St. Louis [c]	P	NA	8	0	1
Mont:	Helena [c]	P	NA	2	0	0
Nebr:	Omaha [c]	P	NA	2	0	0
Nev:	Las Vegas [c]	P	NA	2	0	0
N.H:	Manchester [c]	P	NA	5	0	0
N.J:	Trenton [c]	P	NA	6	0	6
N. Mex:	Albuquerque [c]	P	NA	5	0	1
N.Y:	Buffalo [c]	P	NA	0	0	0
	New York City [c]	P	NA	5	0	2
	Syracuse [c]	P	NA	4	0	2
	Albany	P	NA	6	0	1
	Buffalo	P	4	4	0	0
	Messena	P	4	4	0	0
	New York City	P	8	7	0	0
	Syracuse	P	6	7	0	0
N.C:	Charlotte [c]	P	4	5	0	0
N. Dak:	Minot [c]	P	NA	7	14	5
Ohio:	Cincinnati [c]	P	NA	6	0	0
	Cleveland [c]	P	NA	5	0	3
Okla:	Oklahoma City [c]	P	NA	6	0	2
Oreg:	Portland [c]	P	NA	3	0	0
	Baker	P	NA	4	0	1
	Coos Bay	P	NA			
	Eugene	P	NA			
	Medford	P	NA			
	Portland composite	P	NA			
	Portland local	P	NA			
	Redmond	P	NA			
	Tillamook	P	NA			
Pa:	Philadelphia [c]	P	NA			
	Pittsburgh [c]	P	NA	5	0	1
	Dauphin	P	NA	9	0	2
	Erie	P	5	5	0	0
	Philadelphia	P	5	6	0	0
	Pittsburgh	P	10	5	0	0
R.I:	Providence [c]	P	6	6	0	0
S.C:	Charleston [c]	P	NA	4	0	3
	Anderson-01	R	NA	5	15	7
	Anderson-02	R	7	7	0	0
	Chapin	R	5	5	0	0
	Clemson	R	NS	8	NS	9
	Columbia	R	NS	8	NS	10
	Fairfield	R	NS	8	NS	9
	Hartsville-02	R	NS	7	NS	12
	Hartsville-03	R	NS	6	NS	10
	Lee County	R	NS	15	NS	13
	Oconee County	R	NS	7	NS	14
	Pickens	R	NS	8	NS	7
	Williston	R	7	7	12	9
	Winnsboro	R	8	7	14	16
	York-01	R	NS	7	NS	17
	York-02	R	NS	7	NS	6
S. Dak:	Rapid City [c]	P	NS	5	NS	0
Tenn:	Chattanooga [c]	P	NA	6	0	1
	Knoxville [c]	P	NA	6	0	1
	Memphis [c]	P	NA	0	0	0
	Chattanooga	P	NA	6	0	2
	Clinton	R	6	7	0	5
	Fayetteville	R	10	7	0 (2)	6
	Kingston	R	13	8	0 (2)	6
	Knoxville	P	11	8	0 (2)	3
	Lawrenceburg	R	8	6	0	4
	Nashville	P	6	6	0 (2)	0
	Pulaski	R	NS	5	NS	2
	Sequoyah	R	8	6	0 (2)	2
Tex:	Austin [c]	P	NS	9	NS	6
	Dallas [c]	P	NA	0	0	0
Utah:	Salt Lake City [c]	P	NS	4	NS	0
Vt:	Burlington [c]	P	NA	1	0	0
Va:	Norfolk [c]	P	NA	4	0	5
Wash:	Seattle [c]	P	NA	6	0	1
	Spokane [c]	P	NA	1	0	0
	Benton County	R	NA	5	0	0
	Franklin County	R	NS	0	NS	0
	Longview	R	3	0	0	0
	Sandpoint, Idaho	R	5	5	17	8
	Skagit County	R	3	5	0	1
W. Va:	Charleston [c]	P	0	4	0	0
Wisc:	Milwaukee [c]	P	NA	7	0	2
Wyo:	Laramie [c]	P	NA	4	0	1
			NA	1	0	1

See footnotes at end of table.

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Table 2. Concentrations of radionuclides in milk for March 1974 and 12-month period, April 1973 through March 1974—continued

Sampling location		Type of sample [a]	Radionuclide concentration (pCi/liter)			
			Strontium-90		Cesium-137	
			Monthly average [b]	12-month average	Monthly average [b]	12-month average
CANADA:						
Alberta:	Calgary	P	3	4	3	7
	Edmonton	P	4	5	9	10
British Columbia:	Vancouver	P	5	6	7	12
Manitoba:	Winnipeg	P	4	4	9	9
New Brunswick:	Moncton	P	6	7	9	9
Newfoundland:	St. John's	P	7	12	8	14
Nova Scotia:	Halifax	P	5	6	7	9
Ontario:	Ottawa	P	4	4	10	7
	Sault Ste. Marie	P	8	9	8	14
	Thunder Bay	P	7	6	10	10
	Toronto	P	3	4	NA	
	Windsor	P	2	2	1	5
Quebec:	Montreal	P	5	5	1	6
	Quebec	P	8	8	6	12
Saskatchewan:	Regina	P	5	4	6	6
	Saskatoon	P	5	5	3	6
CENTRAL AND SOUTH AMERICA:						
Canal Zone:	Cristobal [c]	P	NS	0	NS	0
Chile:	Santiago	P	0	0	0	0
Colombia:	Bogota	P	NS	1	NS	0
Ecuador:	Guayaquil	P	0	1	0	1
Jamaica:	Montego Bay	P	NS	2	NS	23
Puerto Rico:	San Juan [c]	P	NA	3	0	2
Venezuela:	Caracas	P	0	0	0	2
PMN network average [d]			NA	4	2	2

[a] P, pasteurized milk.
R, raw milk.

[b] When an individual sampling result was equal to or less than the practical reporting level, a value of "0" was used for averaging. Monthly averages less than the practical reporting level reflect the fact that some but not all of the individual samples making up the average contained levels greater than the practical reporting level. When more than one analysis was made in a month period, the number of samples in the monthly average is given in parentheses.

[c] Pasteurized Milk Network station. All other sampling locations are part of the State or National network.

[d] This entry gives the average radionuclide concentrations for the Pasteurized Milk Network stations denoted by footnote [c].
NA, no analysis.
NS, no sample collected.

stations and the State stations is shown in figure 2. The first column in table 2 under each of the reported radionuclides gives the monthly average for the station and the number of samples analyzed in that month in parentheses. When an individual sampling result is equal to or below the practical reporting level for the radionuclide, a value of zero is used for averaging. Monthly averages are calculated using the above convention. Averages which are equal to or less than the practical reporting levels reflect the presence of radioactivity in some of the individual samples greater than the practical reporting level.

The second column under each of the radionuclides reported gives the 12-month average for the station as calculated from the preceding 12 monthly averages, giving each monthly average equal weight. Since the daily intake of radioactivity by exposed population groups, averaged over a year, constitutes an appropriate criterion for the case where the FRC radiation protection guides apply, the 12-month average serves as a basis for comparison.

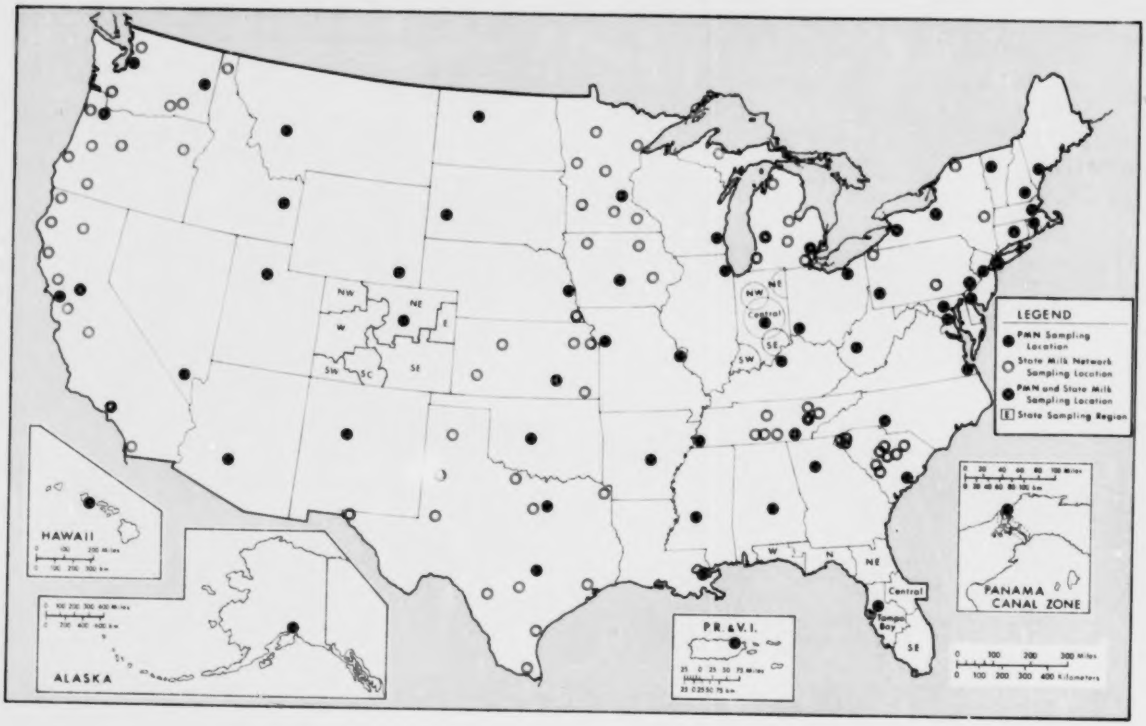
LEGEND
PMN Sampling Location
State Milk Network Sampling Location
PMN and State Milk Sampling Location
E State Sampling Region
NW
NE
W
E
SW
SC
SE
Central
N
Tampa Bay
HAWAII
ALASKA
P.R. & V.I.
PANAMA CANAL ZONE

Figure 2. State and PMN milk sampling stations in the United States

Discussion of current data

In table 2, surveillance results are given for strontium-90 and cesium-137 for March 1974 and the 12-month period, April 1973 to March 1974. Except where noted, the monthly average represents a single sample for the sampling station. Strontium-89, iodine-131, and barium-140 data have been omitted from table 2 since levels at all of the stations for March 1974 were below the respective practical reporting levels.

Strontium-90 monthly averages ranged from 0 to 17 pCi/liter in the United States for March 1974 and the highest 12-month average was 16 pCi/liter (Little Falls and Duluth, Minn.) representing 8.0 percent of the Federal Radiation Council radiation protection guide. Cesium-137 monthly averages ranged from 0 to 59 pCi/liter in the United States for March 1974, and the highest 12-month average was 48 pCi/liter (Southeast Florida) representing 1.3 percent of the value derived from the recommendations given in the Federal Radiation Council report.

The Office of Radiation Programs is in the process of modifying the milk program to make it more responsive to potential sources of environmental radioactivity. These changes will be reflected in future articles.

Acknowledgment

Appreciation is expressed to the personnel of the following agencies who provide data from their milk surveillance networks:

Radiologic Health Section
Environmental Control Component
California Department of Health

Radiation Protection Bureau
Canadian Department of National Health and Welfare

Radiological Health Section
Division of Occupational and Radiological Health
Colorado Department of Health

Laboratory Division
Connecticut Department of Health

Radiological and Occupational Health Section
Department of Health and Rehabilitative Services
State of Florida

Bureau of Environmental Sanitation
Division of Sanitary Engineering
Indiana State Board of Health

Division of Radiological Health
Environmental Engineering Services
Iowa State Department of Health

Radiation Control Section
Environmental Health Division
Kansas State Department of Health

Radiological Health Services
Division of Occupational Health
Michigan Department of Health

Radiation Control Section
Division of Environmental Health
State of Minnesota Department of Health

Bureau of Radiological Pollution Control
New York State Department of Environmental Conservation

Environmental Radiation Surveillance Program
Division of Sanitation and Engineering
Oregon State Board of Health

Radiological Health Section
Bureau of Environmental Health
Pennsylvania Department of Public Health

Division of Radiological Health
South Carolina Department of Health and Environmental Control

Radiological Health Services
Division of Preventable Diseases
Tennessee Department of Public Health

Radiation Control Section
Division of Health
Washington Department of Social and Health Services

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(*2*) U.S. ATOMIC ENERGY COMMISSION, DIVISION OF ISOTOPES DEVELOPMENT. Chart of the nuclides, Tenth Edition revised to December 1968. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402.

(*3*) NATIONAL CENTER FOR RADIOLOGICAL HEALTH. Section I. Milk Surveillance. Radiol Health Data Rep 9:730–746 (December 1968).

(*4*) ROSENSTEIN, M. and A. S. GOLDIN. Statistical technics for quality control of environmental radioassay. Health Lab Sci 2:93 (April 1965).

(*5*) BARATTA, E. J. and F. E. KNOWLES, JR. Interlaboratory Study of iodine-131, cesium-137, strontium-89, and strontium-90 measurements in milk, June 1972, technical experiment 72 MKAQ–1. Analytical Quality Control Service, Office of Radiation Programs, EPA, Washington, D.C. 20460 (December 1972).

(*6*) ROBINSON, P. B. A comparison of results between the Public Health Service Raw Milk and Pasteurized Milk Networks for January 1964 through June 1966. Radiol Health Data Rep 9:475–488 (September 1968).

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Food and Diet Surveillance

Efforts are being made by various Federal and States agencies to estimate the dietary intake of selected radionuclides on a continuing basis. These estimates, along with the guidance developed by the Federal Radiation Council, provide a basis for evaluating the significance of radioactivity in foods and diet.

Networks presently in operation and reported routinely include those listed below. These networks provide data useful for developing estimates of nationwide dietary intakes of radionuclides. Programs reported in *Radiation Data and Reports* are as follows:

Program	Period reported	Issue
California Diet	July 1971–December 1972	February 1974
Carbon-14 in Total Diet and Milk	1972–1973	November 1973
Strontium-90 in Tri-City Diets	1972	December 1973

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SECTION II. WATER

The Environmental Protection Agency and other Federal, State, and local agencies operate extensive water quality sampling and analysis programs for surface, ground, and treated water. Most of these programs include determinations of gross beta and gross alpha radioactivity and specific radionuclides.

Although the determination of the total radionuclide intake from all sources is of primary importance, a measure of the public health importance of radioactivity levels in water can be obtained by comparison of the observed values with the Public Health Service Drinking Water Standards (*1*). These standards, based on consideration of Federal Radiation Council (FRC) recommendations (*2–4*) set the limits for approval of a drinking water supply containing radium-226 and strontium-90 at 3 pCi/liter and 10 pCi/liter, respectively. Higher concentrations may be acceptable if the total intake of radioactivity for all sources remains within the guides recommended by FRC for control action. In the known absence[1] of strontium-90 and alpha-particle emitters, the limit is 1000 pCi/liter gross beta radioactivity, except when additional analysis indicates that concentrations of radionuclides are not likely to cause exposures greater than the limits indicated by the Radiation Protection Guides. Surveillance data from a number of Federal and State programs are published periodically to show current and long-range trends. Water sampling activities reported in *Radiation Data and Reports* are listed below.

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[1] Absence is taken to mean a negligibly small fraction of the specific limits of 3 pCi/liter and 10 pCi/liter for unidentified alpha-particle emitters and strontium-90, respectively.

Water sampling program	Period reported	Issue
California	1971 and 1972	November 1973
Colorado River Basin	1968	March 1972
Community Water Supply Study	1969	September 1972
Florida	1970	April 1974
Interstate Carrier Drinking Water	1971	May 1972
Minnesota	July 1971–June 1972	March 1974
New York	January–December 1972	June 1974
North Carolina	1971	July 1974
Radiostrontium in Tap Water, *HASL*	January–December 1972	December 1973
Washington	July 1970–June 1971	August 1973

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(*2*) FEDERAL RADIATION COUNCIL. Radiation Protection Guidance for Federal Agencies. Memorandum for the President, September 1961. Reprint from the Federal Register of September 26, 1961.

(*3*) FEDERAL RADIATION COUNCIL. Background material for the development of Radiation Protection Standards, Report No. 1. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (May 1960).

(*4*) FEDERAL RADIATION COUNCIL. Background material for the development of Radiation Protection Standards, Report No. 2. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (September 1961).

Radioactivity in Kansas Surface Waters, January–December 1972

Radiation Control Section
Kansas State Department of Health

Monitoring of levels of radioactivity in the surface waters of Kansas is conducted by the Kansas State Department of Health, Radiation Control Section, in cooperation with the Kansas Water Quality Control Section and the U.S. Geological Survey. This surveillance program is important because of both the present and future potential use of Kansas surface waters for domestic, recreational, and industrial purposes.

Liter samples are collected every month at each location shown in figure 1. These samples are analyzed for gross alpha and beta radioactivity. In order to establish baseline data for the two power reactors which are located on the Missouri River in Nebraska, each Missouri River sample is gamma scanned for specific radionuclides. Specific radionuclide analyses are also performed on any other samples which indicate high gross alpha-beta activity. Radioactivity in these waters consists of the natural radioactivity picked up by flowing streams, radioactivity from sewage discharge into the streams, and some contribution by industrial waste. The final contributing factor to radioactivity content is fallout, particularly over large expanses of open water, such as reservoirs and lakes.

Analytical procedures

Radioactivity analyses are performed by the Kansas Radiation Laboratory. Measurements of gross alpha-plus-beta radioactivity are made with a windowless gas-flow proportional counter. Each sample is evaporated in an aluminum planchet, dried at 250° C, and then counted. Specific radionuclide analyses are determined by gamma spectroscopy or chemical separation.

Discussion

Table 1 shows the gross alpha and gross beta radioactivity in the total solids in Kansas surface waters from January through December 1972. These waters are used for domestic, industrial, and recreational purposes. The Arkansas River samples have consistently high activity which is attributed to uranium picked up from its drainage in Colorado.

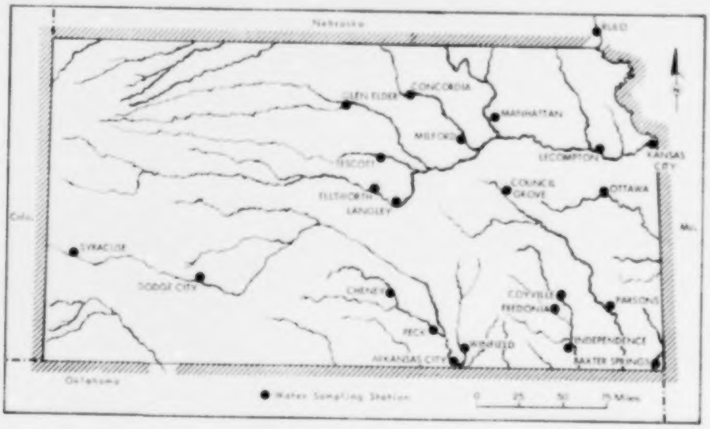
Nebraska
RULO
CONCORDIA
GLEN ELDER
MANHATTAN
MILFORD
LECOMPTON
KANSAS CITY
TESCOTT
ELLSWORTH
LANGLEY
COUNCIL GROVE
OTTAWA
Colo.
Mo.
SYRACUSE
DODGE CITY
CHENEY
COYVILLE
FREDONIA
PARSONS
PECK
WINFIELD
ARKANSAS CITY
INDEPENDENCE
BAXTER SPRINGS
Oklahoma
● Water Sampling Station
0 25 50 75 Miles
N

Figure 1. Kansas surface water sampling stations

Table 1. Gross radioactivity in Kansas surface waters, January-June 1972

Rivers	Sampling stations	Radioactivity concentration (pCi/liter)											
		January		February		March		April		May		June	
		Alpha	Beta	Alpha	Beta	Alpha	Beta	Alpha	Beta	Alpha	Beta	Alpha	Beta
Arkansas	Arkansas City	8	11	14	5	NS	NS	3	12	3	6	5	25
	Dodge City	31	20	NS	NS	23	29	12	12	18	29	51	21
	Syracuse	56	15	34	34	22	6	22	0	75	0	16	0
Big Blue	Manhattan	2	22	2	33	2	9	2	23	1	0	NS	NS
Fall	Fredonia	0	8	4	1	7	0	3	27	1	0	5	31
Kansas	Lecompton	NS	NS	3	13	2	28	1	6	4	31	4	22
Marais des Cygnes	Ottawa	1	0	NS	NS	2	4	0	30	5	1	0	0
Missouri	Kansas City	NS	NS	5	0	5	45	5	28	4	9	NS	NS
	Rulo, Nebr	0	14	7	11	8	35	2	3	6	7	4	8
Neosho	Council Grove	NS	NS	NS	NS	2	5	1	8	3	9	3	0
	Parsons	NS	NS	6	10	2	32	0	8	0	24	2	9
Ninnescah	Cheney Reservoir	3	15	8	21	3	0	0	12	6	17	NS	NS
	Peck	2	6	8	10	3	21	0	7	3	26	1	0
Republican	Concordia	6	7	4	1	12	33	5	29	6	33	10	25
	Milford	7	24	6	0	6	9	2	15	6	53	4	25
Saline	Tescott	0	8	5	30	0	8	6	11	4	31	4	26
Smoky Hill	Ellsworth	0	32	10	0	9	78	11	28	NS	NS	14	14
	Langley	2	26	8	25	9	1	8	0	2	4	2	16
Solomon	Glen Elder	3	49	3	62	6	24	1	17	8	40	0	40
Spring	Baxter Springs	0	3	6	0	0	0	0	13	1	7	0	12
Verdigris	Coyville	0	9	0	0	0	15	0	16	1	18	1	17
	Independence	3	4	3	3	0	8	2	12	3	6	2	16
Walnut	Winfield	4	7	2	8	0	22	0	0	3	19	3	25

Table 1. Gross radioactivity in Kansas surface waters, July-December 1972—continued

Rivers	Sampling stations	Radioactivity concentration (pCi/liter)											
		July		August		September		October		November		December	
		Alpha	Beta	Alpha	Beta	Alpha	Beta	Alpha	Beta	Alpha	Beta	Alpha	Beta
Arkansas	Arkansas City	0	13	0	13	0	25	4	15	6	5	0	0
	Dodge City	19	105	18	41	13	6	20	0	22	0	9	5
	Syracuse	25	93	NS	NS	24	33	29	19	0	22	0	0
Big Blue	Manhattan	3	26	1	12	2	0	2	8	0	0	3	46
Fall	Fredonia	3	15	0	0	0	18	0	5	3	12	0	0
Kansas	Lecompton	3	14	1	25	0	0	NS	NS	0	39	1	22
Marais des Cygnes	Ottawa	2	15	1	19	0	0	NS	NS	3	8	2	34
Missouri	Kansas City	NS	NS	3	30	4	27	1	0	8	0	NS	NS
	Rulo, Nebr	3	32	0	0	5	29	0	0	1	5	NS	NS
Neosho	Council Grove	3	7	5	1	0	6	1	7	2	3	2	0
	Parsons	0	5	0	0	NS	NS	0	17	3	13	0	19
Ninnescah	Cheney Reservoir	3	9	1	0	2	1	0	0	1	8	3	0
	Peck	0	30	0	1	0	16	0	0	0	0	2	0
Republican	Concordia	12	28	11	30	8	25	4	15	0	11	3	0
	Milford	4	21	5	9	2	19	2	0	3	17	4	9
Saline	Tescott	0	30	1	7	0	0	0	0	0	2	1	30
Smoky Hill	Ellsworth	0	50	3	14	2	26	0	0	0	0	0	0
	Langley	0	0	1	5	5	5	0	11	1	9	2	0
Solomon	Glen Elder	2	56	2	45	1	44	3	18	2	17	0	0
Spring	Baxter Springs	NS	NS	NS	NS	4	5	NS	NS	1	0	NS	NS
Verdigris	Coyville	0	21	1	0	0	9	0	0	0	0	0	0
	Independence	1	21	0	11	2	0	0	0	0	0	2	0
Walnut	Winfield	0	15	1	19	4	0	0	0	0	0	2	2

NS, no sample.

Previous coverage in *Radiation Data and Reports:*

Period	Issue
January-December 1971	February 1973

ERAMS Surface and Drinking Water Components January–March 1974

Office of Radiation Programs
Environmental Protection Agency

The Environmental Radiation Ambient Monitoring System (ERAMS), which began in July 1973, was developed from previously operating radiation monitoring networks to form a single monitoring system which is more responsive to current and projected sources of environmental radiation.

Present network

The ERAMS Surface and Drinking Water Components are an expansion of the previous Tritium Surveillance System which was operated by the Office of Radiation Programs from 1970 through June 1973. The Drinking Water Component consists of 76 quarterly drinking water samples taken from major population centers and selected nuclear facility environs (figure 1). The analyses include (a) tritium on a quarterly basis, (b) gamma scan, gross alpha and gross beta radioactive measurements annually with radium-226 and strontium-90 measurements if the gross alpha or gross beta radioactivity exceed 3 or 10 pCi/liter, respectively, and (c) an annual composite for plutonium-238 and -239 on 19 selected sampling locations. The Surface Water Component consists of 55 quarterly surface water samples downstream from nuclear facilities or at a background station (figure 2). The location of the sampling sites was based on all nuclear facilities that were operating, being constructed, or planned through 1976. Tritium analyses are performed quarterly and gamma scans annually. In addition to these components of ERAMS, precipitation samples will be collected at 19 selected locations (figure 1) and tritium measurements

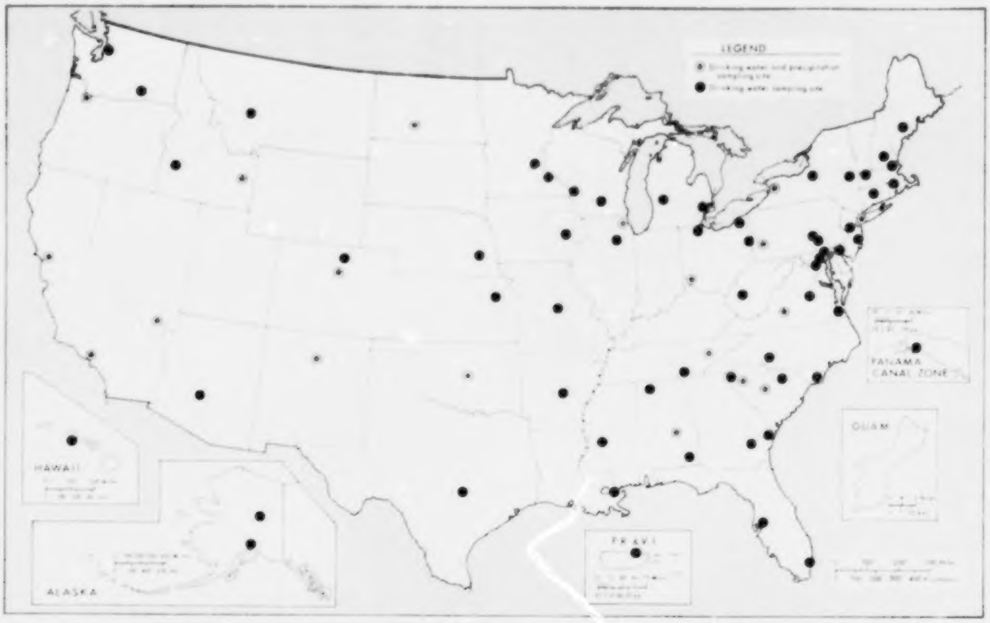
LEGEND
● Drinking water and precipitation sampling site
● Drinking water sampling site
PANAMA CANAL ZONE
GUAM
HAWAII
ALASKA
P R & V I

Figure 1. ERAMS drinking water component and precipitation sampling locations

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are performed on the monthly composite from each station. These 19 locations correspond to air and drinking water sampling locations selected for plutonium analyses. Plutonium-238 and -239 analyses are performed annually on precipitation samples collected in April when elevated levels of rainfall are expected.

Results and discussion

Table 1 presents the tritium concentrations in drinking water at the Drinking Water Component stations for January–March 1974. The average tritium concentration was 0.2 nCi/liter.

In previous articles on the Tritium Surveillance System, the reported dose equivalents from tritium in body water have been based on a relationship derived by Moghissi and Porter (*1*). Their relationship assumed a quality factor of 1.7 for tritium beta rays based on a 1966 ICRP recommendation (*2*). Recently, the NCRP has recommended a quality factor of 1 for tritium beta rays (*3*) and this recommendation has been adopted for this and subsequent reports. Following the notation adopted by the ICRU (*4*) substitution of a quality factor of 1 in Moghissi and Porter calculations yields:

$$\dot{H}\ (\text{mrem/year}) = 0.1\ C\ (\text{nCi/liter})$$

Where $\dot{H}$ is the dose equivalent rate and C represents the tritium concentration in body water in nCi/liter.

It can be assumed for the purpose of calculating dose to members of the population that if the concentration of tritium in all water taken into the body is equal to that found in drinking water and also if that the specific activity of tritium in the body is essentially the same as that in the drinking water, then the radiation dose may be estimated.

The highest individual concentration of tritium observed in drinking water was 3.1 nCi/liter during the fourth quarter. This corresponds to a dose of 0.3 mrem/a.

The tritium concentrations for the Surface Water Component samples are given in table 2. The highest tritium concentration was 4.9 nCi/

Table 1. ERAMS Drinking Water Component, January-March 1974

Location		Date collected (1974)	Tritium concentration [a] (nCi/liter ± 2σ)[b]
Ala:	Dothan	1/3	0
	Montgomery	1/2	0
	Muscle Shoals	1/8	0
Alaska:	Anchorage	NS	
	Fairbanks	1/17	.5
Ark:	Little Rock	1/2	0
Calif:	Berkeley	1/2	.2
	Los Angeles	1/2	0
C.Z:	Ancon	1/21	.5
Colo:	Denver	1/31	.5
	Platteville	3/6	.9
Conn:	Hartford	1/2	0
Del:	Wilmington	1/22	.3
D.C:	Washington	2/11	0
Fla:	Miami	1/2	0
	Tampa	1/2	0
Ga:	Baxley	NS	
	Savannah	1/28	3.1 ± 0.3
Hawaii:	Honolulu	1/11	0
Idaho:	Boise	1/17	.3
	Idaho Falls	1/11	.3
Ill:	Chicago	1/17	1.0
	Morris	1/21	0
Iowa:	Palo	NS	
Kans:	Topeka	1/7	0
La:	New Orleans	1/30	.2
Maine:	Augusta	1/3	.2
Md:	Baltimore	2/28	0
	Conowingo	1/29	0
Mass:	Lawrence	1/2	0
	Rowe	1/21	.3
Mich:	Detroit	1/3	.4
	Grand Rapids	1/8	.3
Minn:	Minneapolis	1/9	.4
	Red Wing	1/10	0
Miss:	Jackson	1/2	0
Mo:	Jefferson City	1/10	0
Mont:	Helena	1/8	.3
Nebr:	Lincoln	1/11	.2
Nev:	Las Vegas	2/27	.8
N.H:	Concord	1/2	0
N.J:	Trenton	2/21	0
	Waretown	2/20	0
N. Mex:	Santa Fe	1/15	.5
N.Y:	Albany	1/7	0
	Buffalo	1/2	.3
	New York City	1/31	.3
	Syracuse	1/29	.6
N.C:	Charlotte	1/2	0
	Wilmington	1/21	0
N. Dak:	Bismarck	1/2	.5
Ohio:	Cincinnati	1/9	0
	East Liverpool	3/21	.4
	Painesville	1/14	0
	Toledo	NS	
Okla:	Oklahoma City	1/3	0
Oreg:	Portland	1/8	0
Pa:	Columbia	1/29	0
	Harrisburg	1/9	0
	Pittsburgh	3/21	.4
P.R:	San Juan	2/1	0
R. I:	Providence	1/2	.2
S. C:	Anderson	1/16	.3
	Columbia	1/2	0
	Hartsville	1/30	0
	Seneca	1/15	.2
Tenn:	Chattanooga	1/3	.5
	Knoxville	1/18	.4
Tex:	Austin	1/7	0
Va:	Doswell	1/7	0
	Lynchburg	1/3	0
	Norfolk	2/22	.2
Wash:	Richland	NS	
	Seattle	1/2	.2
Wisc:	Genoa	1/3	0
	Madison	1/2	0
Average			0.2

[a] The minimum detection limit for all samples was 0.20 nCi/liter. All values equal to or less than 0.20 nCi/liter before rounding have been reported as zero.

[b] The 2σ error for all samples is 0.2 nCi/liter unless otherwise noted.

NS, no sample.

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Table 2. ERAMS Surface Water Component, January-March 1974

Location		Water source	Collection date (1974)	Concentration[a] (nCi/liter ±2σ)[b]	Facility
Ala:	Decatur	Tennessee River	1/7	0.3	Browns Ferry, Sequoyah & Oak Ridge
	Gordon	Chattahoochie River	1/3	.3	Joseph M. Farley
Ark:	Little Rock	Arkansas River	1/14	0	Arkansas Nuclear One
Calif:	Clay Station	Folsom S. Canal	3/20	.2	Rancho Seco
	Diablo Canyon	Pacific Ocean	1/6	0	Diablo Canyon
	Eureka	Humboldt Bay	2/28	4.9±0.3	Humboldt Bay
	San Onofre	Pacific Ocean	3/4	0	San Onofre
Colo:	Greely	South Platte River	3/6	.6	Fort St. Vrain
Conn:	East Haddam	Connecticut River	1/18	.2	Haddam Neck & Vermont Yankee
	Waterford	Long Island Sound	1/21	.3	Millstone
Fla:	Crystal River	Gulf of Mexico	1/31	0	Crystal River
	Ft. Pierce	Atlantic Ocean	1/7	0	St. Lucie
	Homestead	Biscayne Bay	1/8	.4	Turkey Point
Ga:	Baxley	Altamaha River	NS		Edwin T. Hatch
Idaho:	Buhl	Snake River	1/22	.3	National Reactor Testing Station
Ill:	Moline	Mississippi River	1/2	.3	Quad-Cities, Genoa, Prairie Island & Monticello
	Morris	Illinois River	1/21	.3	Dresden & Argonne
	Zion	Lake Michigan	1/4	.2	Zion
Iowa:	Palo	Cedar River	NS		Duane Arnold
La:	New Orleans	Mississippi River	1/3	0	(Several)
Maine:	Wiscasset	Montsweway Bay	1/3	0	Maine Yankee
Md:	Conowingo	Susquehanna River	1/8	0	Peach Bottom & Three Mile Island
	Lusby	Chesapeake Bay	1/8	0	Calvert Cliffs
Mass:	Plymouth	Plymouth Bay	1/2	0	Pilgrim
	Rowe	Deerfield River	1/22	0	Yankee
Mich:	Bridgman	Lake Michigan	1/1	.3	Donald C. Cook
	Charlevoix	Lake Michigan	1/6	.2	Big Rock Point
	Monroe	Lake Erie	1/1	.4	Enrico Fermi
	South Haven	Lake Michigan	1/1	0	Palisades
Minn:	Monticello	Mississippi River	1/17	.7	Monticello
	Red Wing	Mississippi River	1/10	0	Prairie Island & Monticello
Nebr:	Rulo	Missouri River	2/18	.5	Fort Calhoun & Cooper
Nev:	Boulder City	Colorado River	1/7	.7	Background
N.J:	Bayside	Delaware River	NS		Salem
	Oyster Creek	Toms River	2/20	0	Oyster Creek
N.Y:	Ossining	Hudson River	1/7	0	Indian Point
	Oswego	Lake Ontario	1/2	.4	Nine Mile Point, James A. Fitzpatrick & R. E. Ginna
	Poughkeepsie	Hudson River	1/2	0	Background
N.C:	Charlotte	Catawba River	1/2	.3	Wm. B. McGuire
	Southport	Atlantic Ocean	1/22	0	Brunswick
Ohio:	Oak Harbor	Lake Erie	NS		Davis-Besse
Oreg:	Westport	Columbia River	NS		Trojan & Hanford
S.C:	Allendale	Savannah River	1/31	4.0	Savannah River Plant & Oconee
	Hartsville	Lake Robinson	1/30	3.2± .3	H. B. Robinson
Tenn:	Daisy	Tennessee River	2/13	.4	Sequoyah & Oak Ridge
	Kingston	Clinch River	1/17	1.1	Oak Ridge
Tex:	El Paso	Rio Grande	1/2	.3	Los Alamos
Vt:	Vernon	Connecticut River	1/7	.2	Vermont Yankee
Va:	Mineral	North Anna River	1/15	.3	North Anna
	Newport News	James River	1/28	0	Surry
Wash:	Northport	Columbia River	1/29	.5	Background
	Richland	Columbia River	1/2	.4	Hanford
W. Va:	Wheeling	Ohio River	1/3	0	Shippingport & Beaver Valley
Wisc:	Two Creeks	Lake Michigan	1/7	.3	Point Beach & Kewaunee
	Victory	Mississippi River	1/4	.2	Genoa, Prairie Island & Monticello
Average				0.5	

[a] The minimum detection limit for all samples is 0.20 nCi/liter. All values equal to or less than 0.20 nCi/liter before rounding have been reported as zero.

[b] The 2σ error for all samples is 0.2 nCi/liter unless otherwise noted.

NS, no sample.

liter for the quarter. Assuming that the specific activity of tritium in the body is essentially the same as that in surface water, this concentration corresponds to a dose of 0.5 mrem/a.

The monthly analyses for tritium in precipitation samples at the selected stations are shown in table 3.

Other coverage in *Radiation Data and Reports:*

Period	Issue
January–March 1973	July 1973
April–June 1973	October 1973
July–September 1973	May 1974
October–December 1973	June 1974

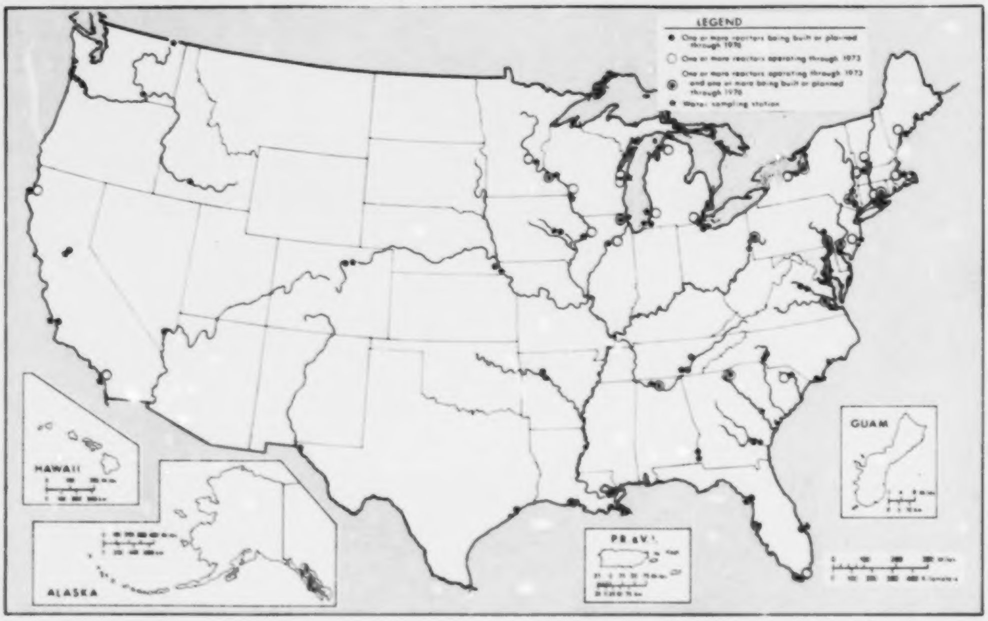
LEGEND
One or more reactors being built or planned through 1976
One or more reactors operating through 1973
One or more reactors operating through 1973 and one or more being built or planned through 1976
Water sampling station
HAWAII
ALASKA
GUAM
PR&VI

Figure 2. ERAMS surface water component sampling stations

Table 3. Tritium concentration in precipitation, January-March 1974

Location		Tritium concentration [a] (nCi/liter ± 2σ)		
		January	February	March
Ala:	Montgomery	0.4	0.7	0.3
Calif:	Berkeley	0	0	0
	Los Angeles	NS	NS	NS
Colo:	Denver	.2	.9	.4
Idaho:	Idaho Falls	0	0	.3
Ill:	Chicago	NS	NS	NS
Nev:	Las Vegas	NS	0	.2
N. Mex:	Santa Fe	0	NS	.3
N.Y:	Buffalo	0	.3	.3
	New York City	NS	NS	NS
N. Dak:	Bismarck	0	0	.5
Ohio:	Cincinnati	NS	NS	NS
Okla:	Oklahoma City	NS	NS	NS
Oreg:	Portland	NS	NS	NS
Pa:	Pittsburgh	NS	NS	NS
S.C:	Anderson	NS	NS	NS
	Columbia	.4	.3	.5
Tenn:	Knoxville	NS	NS	NS
Va:	Lynchburg	NS	NS	NS

[a] The minimum detection limit for these samples was 0.20 nCi/liter. All values equal to or less than 0.20 nCi/liter before rounding have been reported as zero. The 2σ error for all samples is 0.2 nCi/liter unless otherwise noted.

NS, no sample.

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(1) MOGHISSI, A. A. and C. R. PORTER. Tritium in surface waters in the United States, 1966. Radiol Health Data Rep 9:337–339 (July 1968).

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SECTION III. AIR AND DEPOSITION

Radioactivity in Airborne Particulates and Precipitation

Continuous surveillance of radioactivity in air and precipitation provides one of the earliest indications of changes in environmental fission product radioactivity. To date, this surveillance has been confined chiefly to gross beta radioanalysis. Although such data are insufficient to assess total human radiation exposure from fallout, they can be used to determine when to modify monitoring in other phases of the environment.

Surveillance data from a number of programs are published monthly and summarized periodically to show current and long-range trends of atmospheric radioactivity in the Western Hemisphere. These include data from activities of the Environmental Protection Agency, the Canadian Department of National Health and Welfare, and the Pan American Health Organization.

In addition to those programs presented in this issue, the following programs were covered previously in *Radiation Data and Reports.*

Network	Period	Issue
Fallout in the United States and other areas, HASL	1971	August 1973
Krypton-85 in air	July 1970–1972	March 1974
Mexican air monitoring program	July–December 1973	May 1974
Plutonium in airborne particulates	April–June 1973	June 1974

1. Radiation Alert Network
March 1974

Eastern Environmental Radiation Facility
Environmental Protection Agency

Surveillance of atmospheric radioactivity in the United States is conducted by the Radiation Alert Network (RAN). Samples are collected at 68 locations throughout the country (figure 1). Most of the stations are operated by State health department personnel.

The station operators perform "field estimates" on the airborne particulate samples at 5 hours after collection, when most of the radon daughter products have decayed, and at 29 hours after collection, when most of the thoron daughter products have decayed. The airborne particulate samples and precipitation samples are sent to the Eastern Environmental Radiation Facility for further analysis. All field estimate results are reported to appropriate Environmental Protection Agency officials by mail or telephone depending on levels found. A compilation of the daily measurements is available upon request from the Eastern Environmental Radiation Facility, Montgomery, Ala. 36109. A detailed description of the sampling and analytical procedures was presented in the March 1968 issue of *Radiological Health Data and Reports.*

Table 1 presents the monthly average gross beta radioactivity in surface air particulates and deposition by precipitation, as measured by the field estimate and laboratory techniques during March 1974.

The Office of Radiation Programs is in the process of modifying the air program to make it more responsive to potential sources of environmental radioactivity. These changes will be reflected in future articles.

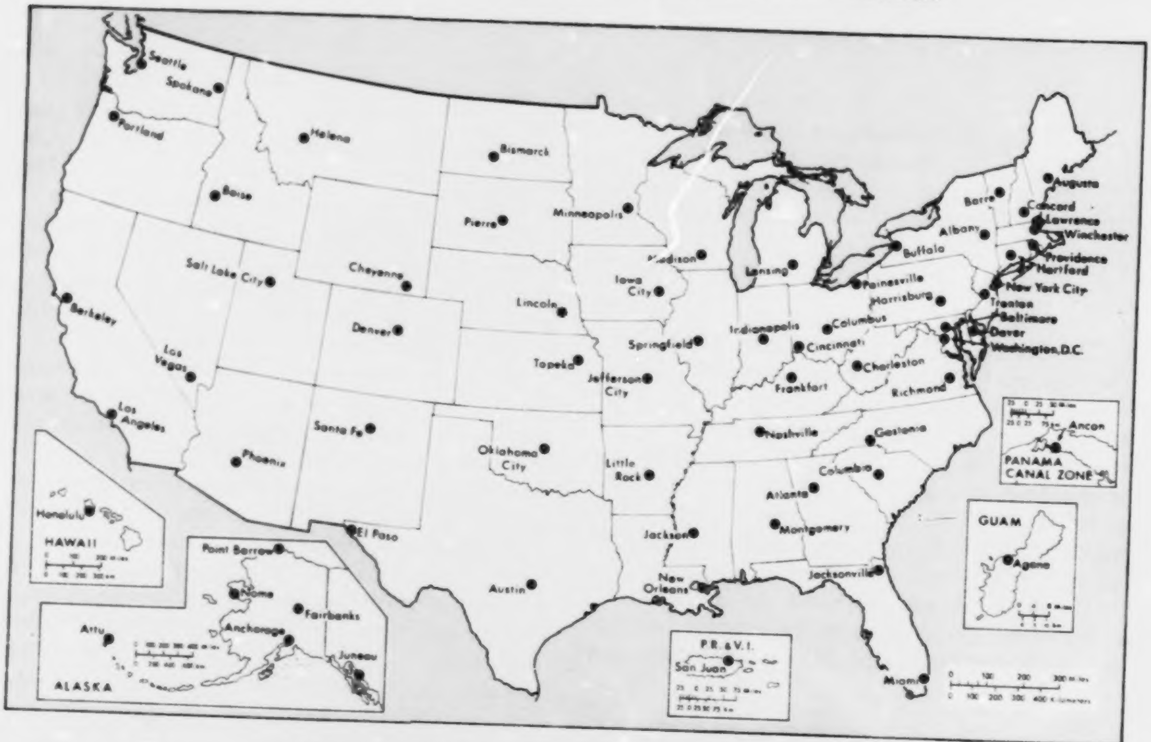
Seattle
Spokane
Portland
Helena
Bismarck
Boise
Pierre
Minneapolis
Augusta
Barre
Concord
Lawrence
Winchester
Albany
Buffalo
Providence
Hartford
Madison
Lansing
Painesville
Salt Lake City
Cheyenne
Iowa City
Harrisburg
New York City
Trenton
Baltimore
Dover
Washington, D.C.
Lincoln
Berkeley
Denver
Indianapolis
Columbus
Springfield
Cincinnati
Las Vegas
Topeka
Jefferson City
Charleston
Frankfort
Richmond
Los Angeles
Santa Fe
Nashville
Gastonia
Ancon
PANAMA CANAL ZONE
Oklahoma City
Little Rock
Columbia
Phoenix
Atlanta
Honolulu
HAWAII
Point Barrow
El Paso
Jackson
Montgomery
GUAM
Agana
Nome
Fairbanks
Jacksonville
Austin
New Orleans
Attu
Anchorage
Juneau
ALASKA
P.R. & V.I.
San Juan
Miami

Figure 1. Radiation Alert Network sampling stations

Table 1. Gross beta radioactivity in surface air and precipitation, March 1974

Station location [a]		Number of samples	Gross beta radioactivity (pCi/m^3)						Precipitation	
			5-hour field estimate			Laboratory measurement			Laboratory estimate of deposition	
			Maximum	Minimum	Average [b]	Maximum	Minimum	Average [b]	Depth (mm)	Total deposition (nCi/m^2)
Ala:	Montgomery	9	1	0	1	0.15	0.04	0.10	51	0.76
Alaska:	Anchorage	1	0	0	0	.07	.07	.07		
Calif:	Berkeley	9	0	0	0	.15	.04	.08	33	.18
	Los Angeles	9	1	0	1	.36	.08	.15		
Colo:	Denver	9	2	1	1	.40	.16	.25	15	.59
Idaho:	Idaho Falls	8	---	---	---	.19	.06	.12	42	1.23
Ind:	Indianapolis	8	0	0	0	.14	.06	.09		
Nev:	Las Vegas	8	2	1	1	.27	.11	.19	8	.06
N. Mex:	Santa Fe	4	1	0	1	.30	.12	.21	9	.39
N.Y:	Buffalo	9	0	0	0	.17	.08	.10	1	.02
N. Dak:	Bismarck	9	1	0	1	.14	.06	.08	6	.08
Ohio:	Columbus	5	1	0	0	.13	.08	.11		
Okla:	Oklahoma City	5	1	0	1	.18	.08	.11		
Oreg:	Portland	21	0	0	0	.15	.02	.07		
Pa:	Harrisburg	19	1	0	0	.20	.04	.08		
S.C:	Columbia	9	1	0	1	.20	.06	.13	30	.64
Network summary		142	2	0	1	0.40	0.02	0.12	22	0.44

[a] The remaining stations are on standby status.

[b] The monthly average is calculated by weighting the estimates of individual air samples with length of sampling period.

2. Air Surveillance Network
March 1974

National Environmental Research Center—
Las Vegas
Environmental Protection Agency

The Air Surveillance Network,[1] operated by the National Environmental Research Center—Las Vegas (NERC-LV), consists of 49 active and 72 standby sampling stations located in 21 western States (figures 2 and 3). The network is operated in support of nuclear testing sponsored by the U.S. Atomic Energy Commission (AEC) at the Nevada Test Site (NTS), and at any other designated testing sites.

The stations are operated by State health department personnel and by private individuals on a contract basis. All active stations are operated continuously with filters being exchanged after periods generally ranging from 48 to 72 hours. All samples are mailed to the NERC-LV unless special retrieval is arranged at selected locations in response to known releases of radioactivity from the NTS. A complete description of sampling and analytical procedures was presented in the February 1972 issue of *Radiation Data and Reports*.

Table 2 presents the average gross beta concentrations in air for each of the network stations. The minimum reporting concentration for gross beta activity is 0.1 pCi/m^3. For reporting purposes, concentrations less than 1.0 pCi/m^3 are reported to one significant figure, and those equal to or greater than 1.0 pCi/m^3 are reported to two significant figures. For averaging purposes individual concentrations values less than the minimum detectable concentration (~0.03 pCi/m^3 for a 700 m^3 sample) are set equal to the minimum detectable concentration (MDC). Reporting an drounding-off conventions are as follows:

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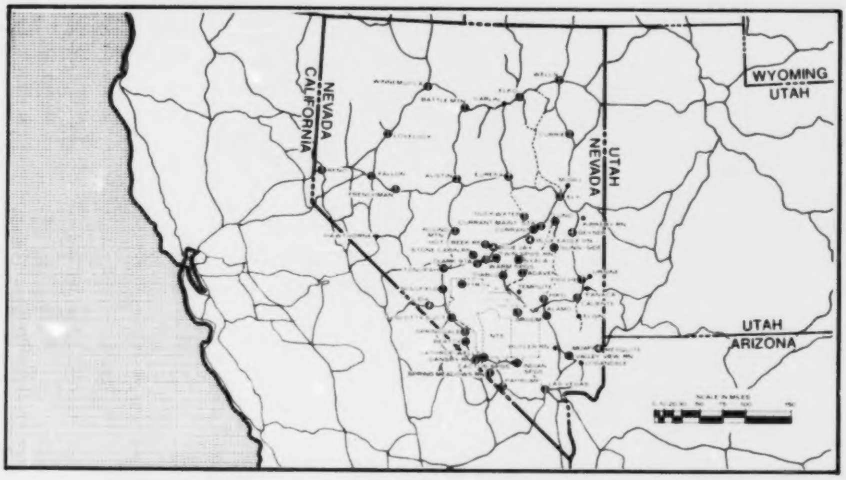
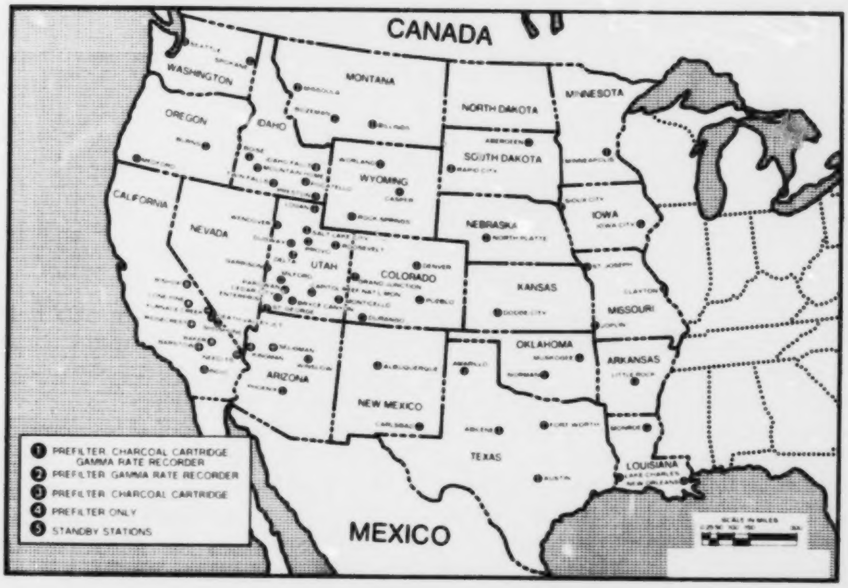
[1] This network is operated under a Memorandum of Understanding (No. AT 26-1)-539) with the Nevada Operations Office, U.S. Atomic Energy Commission.

Concentration (pCi/m³)	Reported value of concentration above MDC (pCi/m³)	Reported value of concentration below MDC (pCi/m³)
<0.05	<0.1	<0.1
≥0.05, <0.15	0.1	<0.1
≥0.15	As calculated and rounded	< calculated MDC



NEVADA
CALIFORNIA
UTAH
NEVADA
WYOMING
UTAH
UTAH
ARIZONA
SCALE IN MILES

Figure 2. NERC-LV Air Surveillance Network stations in Nevada



CANADA
WASHINGTON
MONTANA
NORTH DAKOTA
MINNESOTA
OREGON
IDAHO
SOUTH DAKOTA
WYOMING
CALIFORNIA
NEVADA
NEBRASKA
IOWA
UTAH
COLORADO
KANSAS
MISSOURI
OKLAHOMA
ARKANSAS
ARIZONA
NEW MEXICO
TEXAS
LOUISIANA
MEXICO
SCALE IN MILES
1 PREFILTER CHARCOAL CARTRIDGE GAMMA RATE RECORDER
2 PREFILTER GAMMA RATE RECORDER
3 PREFILTER CHARCOAL CARTRIDGE
4 PREFILTER ONLY
5 STANDBY STATIONS

Figure 3. NERC-LV Air Surveillance Network stations outside Nevada

Table 1. Summary of gross beta radioactivity concentrations in air, March 1974

Station location		Number of samples	Concentration (pCi/m³)		
			Maximum	Minimum	Average [a]
Ariz:	Kingman	13	.6	<0.1	0.3
	Seligman	13	.5	<.1	.3
Calif;	Baker	13	1.0	.2	.4
	Barstow	13	.5	<.1	.2
	Bishop	13	.9	.1	.5
	Death Valley Junction	13	1.4	.1	.5
	Furnace Creek	13	.7	<.1	.4
	Lone Pine	10	.5	<.1	.3
	Needles	12	.6	.3	.4
	Ridgecrest	13	.5	<.1	.3
	Shoshone	13	.6	<.1	.4
Nev:	Alamo	13	1.6	<.1	.4
	Austin	12	.6	.1	.2
	Beatty	13	.6	<.1	.3
	Blue Eagle Ranch (Currant)	13	.7	<.1	.3
	Blue Jay	13	.7	<.1	.3
	Caliente	13	.5	<.1	.3
	Currant Ranch	13	.6	<.1	.3
	Diablo	13	.7	<.1	.4
	Duckwater	13	.6	<.1	.2
	Ely	13	.5	<.1	.3
	Eureka	13	1.3	<.1	.4
	Fallini's Twin Springs Ranch	13	.7	<.1	.3
	Geyser Ranch (Pioche)	6	.6	<.1	.3
	Goldfield	13	.6	<.1	.2
	Groom Lake	13	.6	<.1	.3
	Hiko	13	.6	<.1	.3
	Indian Springs	13	.6	<.1	.3
	Las Vegas	15	1.1	.1	.4
	Lathrop Wells	13	.5	<.1	.3
	Lida	13	.9	<.1	.3
	Lund	13	.8	<.1	.4
	Mesquite	13	.5	<.1	.3
	Nyala	13	.8	<.1	.4
	Pahrump	13	.5	<.1	.3
	Pioche	13	.7	<.1	.3
	Round Mountain	5	.3	.1	.2
	Scotty's Junction	14	.7	.1	.4
	Stone Cabin Ranch	13	.6	<.1	.3
	Sunnyside	13	.6	.1	.3
	Tonopah	13	.5	<.1	.2
	Tonopah Test Range	11	.5	<.1	.3
	Warm Springs	3	.5	<.1	.3
	Warm Springs Ranch	13	.5	<.1	.3
Utah:	Cedar City	13	.6	<.1	.3
	Delta	13	.6	<.1	.3
	Garrison	13	.7	<.1	.3
	Milford	13	.8	.2	.4
	St. George	13	.5	<.1	.4

[a] Individual values less than the minimum detectable concentration (MDC) are set equal to the MDC for averaging. A monthly average less than the minimum reportable value of 0.1 pCi/m³ is reported as <0.1.

As shown by table 2, the highest gross beta concentration within the network was 1.6 pCi/m³ at Alamo, Nev.

From gamma spectrometry results, fission products in varying combinations of zirconium-95, ruthenium-103, and cerium-141 were identified on filters collected in Arizona, California, Nevada, and Utah. The highest concentrations of these radionuclides, respectively were 0.41 pCi/m³ (Blue Eagle Ranch, Currant, Nev.), 0.36 pCi/m³ and 0.28 pCi/m³ (Alamo, Nev.). These radionuclides are attributed to annual worldwide fallout. No radionuclides were identified by gamma spectrometry on any charcoal cartridges during March.

Complete copies of this summary and listings of the daily gross beta and gamma spectrometry results are distributed to EPA Regional Offices and appropriate State agencies. Additional copies of the daily results may be obtained from the NERC-LV upon written request.

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3. Canadian Air and Precipitation Monitoring Program,[3] March 1974

Radiation Protection Division
Department of National Health and Welfare

The Radiation Protection Bureau of the Canadian Department of National Health and Welfare monitors surface air and precipitation in connection with its Radioactive Fallout Study Program. Twenty-four collection stations are located at airports (figure 4), where the sampling equipment is operated by personnel from the Atmospheric Environment Service of the Department of the Environment. Detailed discussions of the sampling procedures, methods of analysis, and interpretation of results of the radioactive fallout program are contained in reports of the Department of National Health and Welfare (*1–5*).

A summary of the sampling procedures and methods of analysis was presented in the May 1969 issue of *Radiological Health Data and Reports.*

Surface air and precipitation data for March 1974 are presented in table 3.

Table 3. Canadian gross beta radioactivity in surface air and precipitation, March 1974

Station	Number of samples	Air surveillance gross beta radioactivity (pCi/m³)			Precipitation measurements	
		Maximum	Minimum	Average	Average concentration (pCi/liter)	Total deposition (nCi/m²)
Calgary	4	0.08	0.06	0.07	28.0	0.5
Coral Harbour	4	.08	.05	.07	315.2	.4
Edmonton	4	.08	.07	.08	15.0	.7
Ft. Churchill	4	.06	.05	.06	53.4	.6
Fredericton	4	.08	.05	.07	22.0	1.8
Goose Bay	4	.05	.03	.04	10.5	.6
Halifax	4	.08	.04	.06	5.7	.6
Inuvik	1	.06	.06	.06	196.9	.1
Montreal	4	.06	.04	.05	23.7	2.2
Moosonee	4	.07	.05	.06	6.1	.2
Ottawa	3	.08	.03	.06	16.9	2.0
Quebec	4	.08	.06	.07	16.5	1.5
Regina	4	.09	.05	.07	38.0	.7
Resolute	4	.06	.05	.06	6.4	.2
St. John's, Nfld	3	.03	.01	.02	25.8	4.2
Saskatoon	4	.08	.05	.07	12.7	.4
Sault Ste. Marie	4	.09	.06	.07	27.7	1.2
Thunder Bay	4	.06	.04	.05	45.8	1.6
Toronto	0				94.7	5.4
Vancouver	4	.04	.03	.04	19.4	3.6
Whitehorse	4	.10	.06	.08	32.3	.3
Windsor	0				46.7	5.4
Winnipeg	4	.08	.05	.07	61.1	.9
Yellowknife	4	.05	.03	.04	22.3	.3
Network summary	83	0.10	0.01	0.06	47.6	1.5

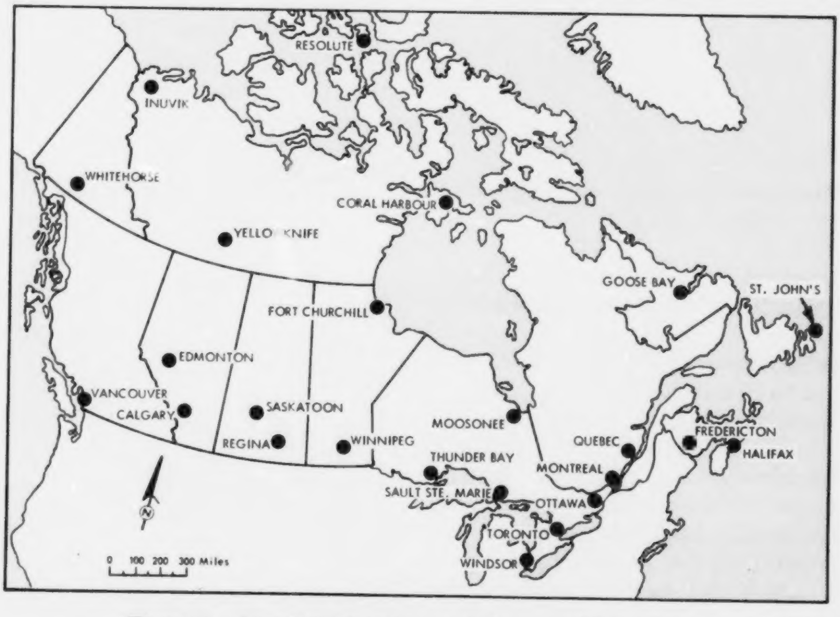
RESOLUTE
INUVIK
WHITEHORSE
CORAL HARBOUR
YELLOWKNIFE
GOOSE BAY
ST. JOHN'S
FORT CHURCHILL
EDMONTON
VANCOUVER
CALGARY
SASKATOON
REGINA
WINNIPEG
MOOSONEE
QUEBEC
FREDERICTON
HALIFAX
THUNDER BAY
MONTREAL
SAULT STE. MARIE
OTTAWA
TORONTO
WINDSOR
N
0 100 200 300 Miles

Figure 4. Canadian air and precipitation sampling stations

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[3] Prepared from information and data obtained from the Canadian Department of National Health and Welfare, Ottawa, Canada.

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(4) BEALE, J. and J. GORDON. The operation of the Radiation Protection Division Air Monitoring Program, RPD-11. Department of National Health and Welfare, Ottawa, Canada (July 1962).

(5) BOOTH, A. H. The calculation of permissible levels of fallout in air and water and their use in assessing the significance of 1961 levels in Canada, RPD-21. Department of National Health and Welfare, Ottawa, Canada (August 1962).

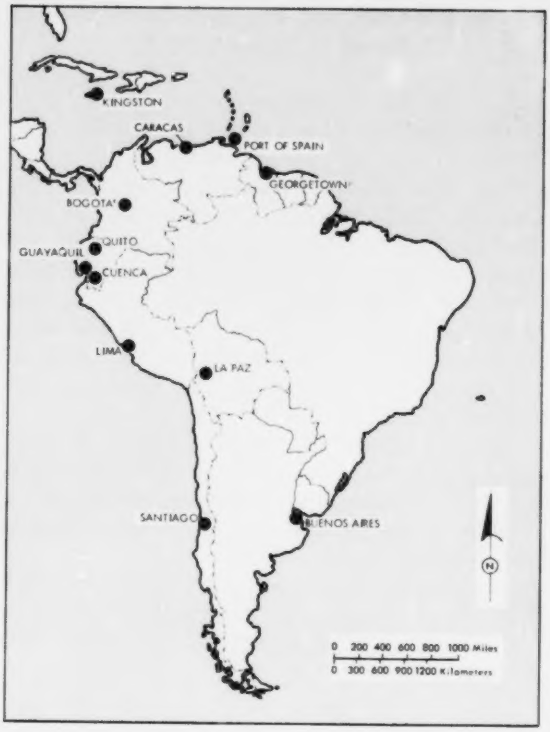

Figure 5. Pan American Air Sampling Program stations

4. Pan American Air Sampling Program March 1974

Pan American Health Organization and U.S. Environmental Protection Agency

Gross beta radioactivity in air is monitored by countries in the Americas under the auspices of the collaborative program developed by the Pan American Health Organization (PAHO) and the Environmental Protection Agency (EPA) to assist PAHO-member countries in developing radiological health programs.

The air sampling station locations are shown in figure 5. Analytical techniques were described in the March 1968 issue of *Radiological Health Data and Reports.* The March 1974 air monitoring results from the participating countries are given in table 4.

Table 4. Summary of gross beta radioactivity in Pan American surface air, March 1974

Station location		Number of samples	Gross beta radioactivity (pCi/m³)		
			Maximum	Minimum	Average [a]
Argentina:	Buenos Aires	0			
Bolivia:	La Paz	0			
Chile:	Santiago	0			
Colombia:	Bogota	19	0.10	0.01	0.02
Ecuador:	Cuenca	16	.02	.00	.01
	Guayaquil	14	.03	.01	.02
	Quito	13	.02	.00	.01
Guyana:	Georgetown	0			
Jamaica:	Kingston	0			
Peru:	Lima	16	.02	.01	.01
Trinidad and Tobago:	Port of Spain	0			
Venezuela:	Caracas	10	.06	.02	.04
Pan American summary		88	0.10	0.00	0.02

[a] The monthly average is calculated by weighting the individual samples with length of sampling period. Values less than 0.005 pCi/m³ are reported and used in averaging as 0.00 pCi/m³.

5. California Air Sampling Program March 1974

Radiologic Health Section
California Department of Health

The Radiologic Health Section of the California Department of Health with the assistance of several cooperating agencies and organizations operates a surveillance system for determining radioactivity in airborne particulates. The air sampling locations are shown in figure 6.

One of the objectives of the program is to evaluate the possibility that fixed effluent sources contribute to particulate activity in the air. Consequently, data from continuous air samplers placed in proximity to nuclear facilities are compared with those from similiar equipment in nearby communities and at several "background" stations.[1]

Airborne particles are collected by a continuous sampling of air filtered through a 47

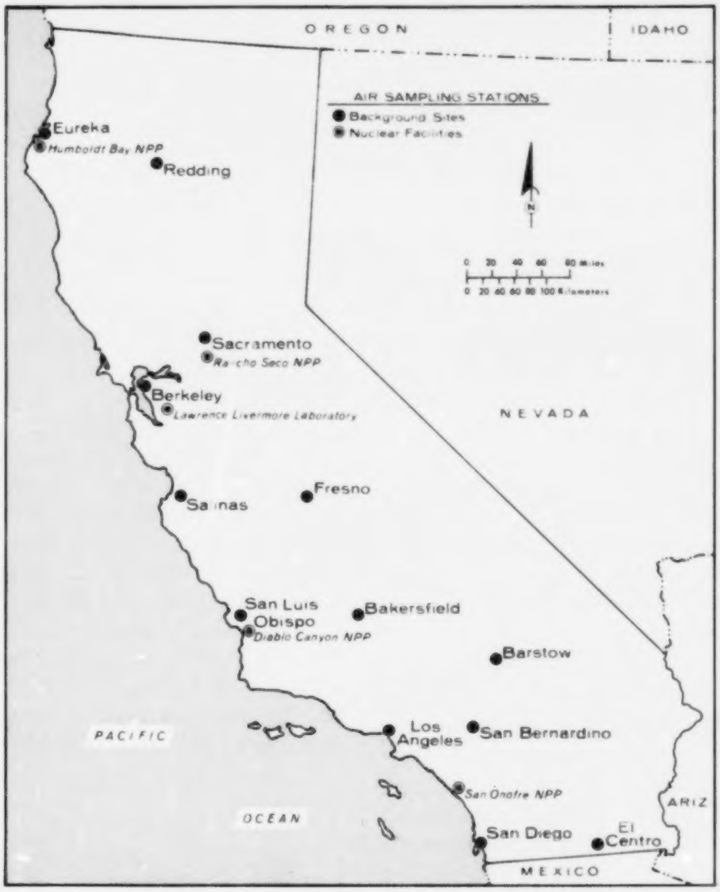
OREGON
IDAHO
AIR SAMPLING STATIONS
● Background Sites
● Nuclear Facilities
N
0 20 40 60 80 Miles
0 20 40 60 80 100 Kilometers
Eureka
Humboldt Bay NPP
Redding
Sacramento
Rancho Seco NPP
Berkeley
Lawrence Livermore Laboratory
NEVADA
Fresno
Salinas
San Luis Obispo
Diablo Canyon NPP
Bakersfield
Barstow
PACIFIC
Los Angeles
San Bernardino
San Onofre NPP
ARIZ
OCEAN
San Diego
El Centro
MEXICO

Figure 6. California air sampling program stations

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[1] Air samples near nuclear power reactors were obtained under contract number AT(49-1)-3549 between the U.S. Atomic Energy Commission and the California Department of Health.

millimeter membrane filter, 0.8 micron pore size, using a Gast air pump of about 2 cubic feet per minute capacity, or 81.5 cubic meters per day. Air volumes are measured with a direct reading gas meter. Filters are replaced every 24 hours except on holidays and weekends.

All air samples are sent to the Sanitation and Radiation Laboratory of the State Department of Health. The filters are analyzed for gross alpha and beta radioactivity 72 hours after the end of the collection period. The daily samples then are composited into a monthly sample for gamma spectroscopy and an analysis for strontium-89 and strontium-90. The monthly sample results are presented quarterly. Table 5 presents the gross beta radioactivity in air for March 1974.

Table 5. Gross beta radioactivity in California air, March 1974

Station location	Number of samples	Gross beta radioactivity (pCi/m³)		
		Maximum	Minimum	Average
Bakersfield	19	0.74	0.14	0.34
Barstow	30	.80	.02	.41
Berkeley	31	.46	.00	.22
Diablo Canyon Nuclear Power Plant	8	.39	.12	.21
El Centro	20	.70	.25	.44
Eureka	19	.39	.07	.16
Fresno	21	.75	.11	.30
Humboldt Bay Nuclear Power Plant	13	.30	.07	.15
Los Angeles	21	.85	.04	.29
Rancho Seco Nuclear Power Plant	13	.53	.12	.25
Redding	15	.75	.14	.34
Sacramento	21	.46	.01	.19
Salinas	20	.46	.10	.22
San Bernardino	15	.58	.20	.35
San Diego	21	.59	.15	.35
San Luis Obispo	20	.56	.06	.25
San Onofre Nuclear Generating Station	3	.39	.09	.17
Livermore	21	.56	.06	.25
Summary	331	0.85	0.00	0.27

Fallout in the United States and Other Areas[1] January–December 1972

Health and Safety Laboratory
Atomic Energy Commission

Monthly fallout deposition rates for strontium-90 are determined by the Health and Safety Laboratory (HASL) for 35 sites in the United States and 90 locations in other countries. HASL data from all of the active United States stations and other selected points in the Western Hemisphere (figure 1) covering the period from January–December 1972 are summarized in tables 1 and 2.

All the stations of the 80th Meridian Network are represented.

Methods of collection

Two methods of fallout collection are employed by HASL. In the first, precipitation and dry fallout are collected for a period of 1 month in a stainless steel pot with an exposed area of 0.076 m². At the end of the collection period, the contents are transferred, by careful scrubbing with a rubber spatula, to a polyethylene sample bottle which is then shipped to the laboratory for analysis.

The second method involves the use of a polyethylene funnel, with an exposed area of 0.072 m², attached to an ion exchange column. After a 1-month collection, the inside of the funnel is wiped with a tissue, and the tissue is inserted in the end of the column, which is then sealed and sent to HASL for analysis. It has been shown that at the 95-percent confidence level there are no significant differences in the strontium-90 measurements obtained from samples collected by the two methods (*1*).

REFERENCE

(*1*) ONG, L. D. Y. Homogeneity between pot and ion exchanges column strontium-90 measurements. Fallout Program Quarterly Summary Report, HASL-135:256-269. Office of Technical Services, Department of Commerce, Washington, D.C. (April 1, 1963).

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[1] The data in this article were taken from "Fallout Program Quarterly Summary Report, HASL-278," APP:A1 to A-320.

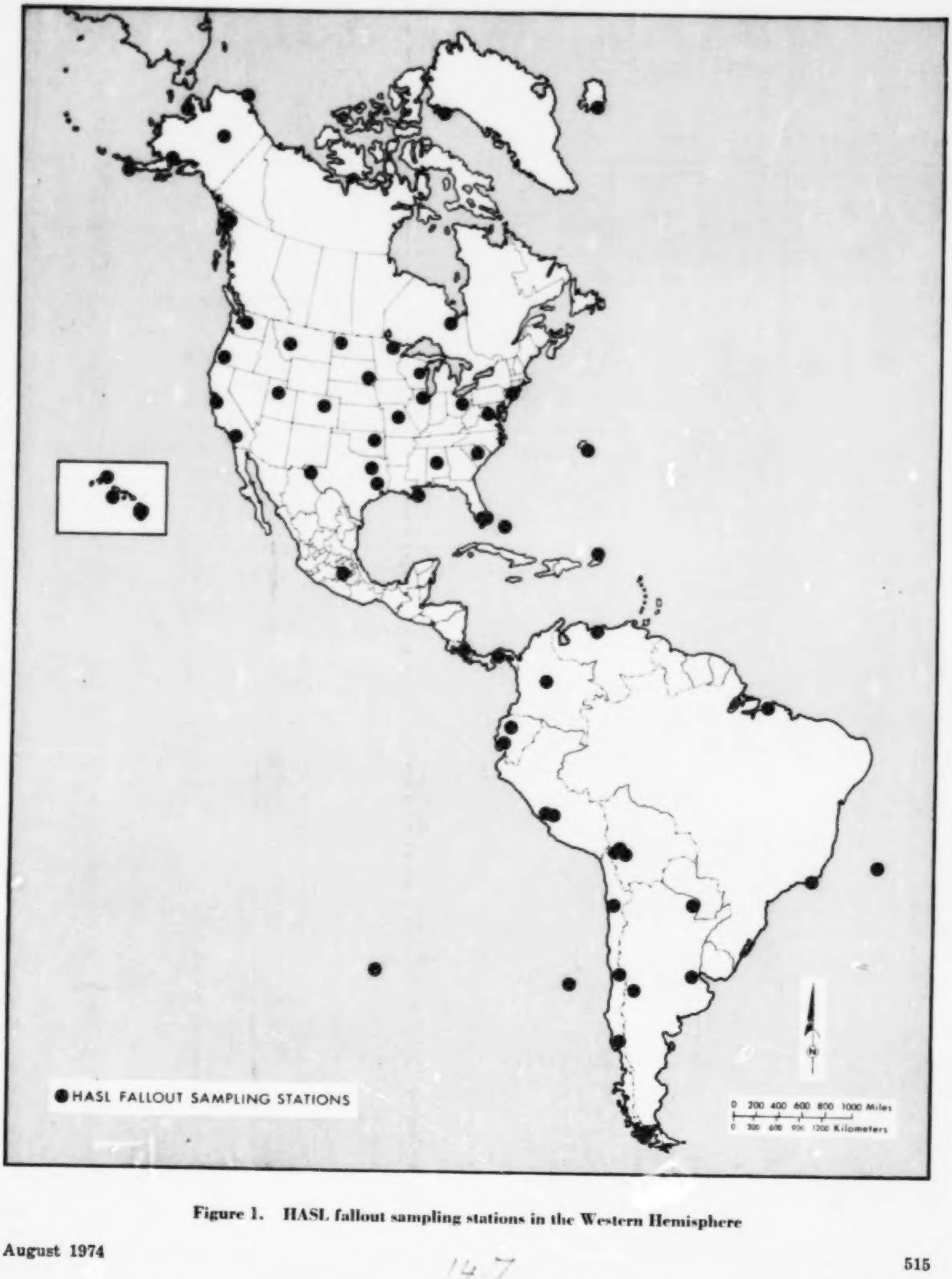
● HASL FALLOUT SAMPLING STATIONS
0 200 400 600 800 1000 Miles
0 300 600 900 1200 Kilometers
N

Figure 1. HASL fallout sampling stations in the Western Hemisphere

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Table 1. Strontium-90 fallout in the United States, HASL, January-December 1972

Sampling location		Type of collection	Deposition (nCi/m²)											
			Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Ala:	Birmingham	pot	0.06	0.06	0.09	0.04	0.06	0.04	0.05	0.02	0.02	0.03	0.01	0.03
Alaska:	Anchorage	column	.02	(a)	(a)	(a)	.04	.02	.02	.03	(b)	.04	(b)	(b)
	Cold Bay	column	.05	(a)	(a)	.04	.03	.04	.06	.03	.02	.03	.03	.02
	Fairbanks	column	(b)	(b)	(b)	(a)	(b)	(b)	(b)	(b)	(b)	(a)	(a)	(a)
	Juneau	column	(a)	.04	.07	.02	.15	.05	.02	.09	.04	.04	.02	.03
	Nome	column	(a)	(a)	(a)	(a)	(b)	.06	.04	(b)	.03	.01	(a)	(b)
Calif:	W. Los Angeles	pot	(a)	.18	(a)	(a)	.02	.01	(a)	(a)	(a)	(a)	.02	(a)
	San Francisco	column	.02	.04	(a)	.02	(a)	(a)	.02	(a)	(a)	.02	.02	.02
Colo:	Denver	column	(a)	.01	.02	.05	.06	(b)	.20	.01	(a)	(b)	(b)	.03
Fla:	Miami	column	.02	(a)	.02	.02	.18	.06	.05	.03	.02	(a)	.01	.02
Hawaii:	Honolulu	pot	(b)	.14	(b)	.15	.06	.04	(b)	(b)	(b)	(b)	(b)	(b)
	Lihue	column	.05	.08	.04	.15	.02	.04	(a)	.01	.02	.01	(a)	(a)
	Mauna Loa	column	.10	.02	.02	.02	.02	.01	.03	(a)	(a)	(a)	(a)	.04
Ill:	Argonne	pot	.02	.03	.07	.10	.09	.08	.06	.07	.01	(a)	.02	.02
La:	New Orleans	column	.05	.07	.11	.04	.06	.06	.05	.02	.01	.01	.02	.02
Minn:	International Falls	column	.01	(a)	.02	.03	(b)	.06	.09	.04	.02	(a)	(a)	(a)
Mo:	Columbia	column	(a)	.02	.12	.12	.08	.03	.03	.02	.02	.01	.01	.02
Mont:	Helena	column	.04	.01	.02	.02	.06	.06	.05	.03	(a)	.01	(a)	(a)
N.Y:	New York City	pot	.06	.07	.10	.09	.10	.12	.09	.02	.02	(a)	.04	.04
N. Dak:	Williston	column	(a)	(a)	(b)	.06	.13	.10	(b)	.04	.02	(a)	(a)	(a)
Ohio:	Wooster	pot	.02	.02	.02	.04	.04	.03	.02	(a)	(a)	(a)	(a)	(a)
Okla:	Tulsa	pot	(a)	(b)	[c].05	[c].05	.07	.06	[c].01	[c].01	.02	.02	.01	.01
Oreg:	Medford	column	.02	.04	.04	.02	.06	.08	(a)	(b)	.02	(a)	(a)	.05
S.C:	Columbia	column	(a)	.04	.09	.03	.11	.05	.09	.02	(a)	(a)	.02	.05
S. Dak:	Vermillion	pot	(a)	.01	.03	.13	.38	.09	(b)	.04	.04	.02	.02	.02
Tex:	Dallas	column	(a)	.01	.03	.08	.02	.04	.02	(b)	.03	.02	.01	.02
	El Paso	column	.01	(a)	(a)	(a)	.02	(b)	.08	[c].02	[c].01	(a)	(a)	(a)
	Houston	column	.02	(a)	.03	.04	.08	.02	.04	.02	(a)	(a)	(a)	.02
Utah:	Salt Lake City	pot	(b)	.14	.08	.08	.09	.06	.02	.02	.01	.03	(a)	(a)
Va:	Sterling	column	.04	.04	.03	.09	.05	.08	.06	.03	(a)	.02	.02	.02
Wash:	Seattle	pot	.05	.06	.11	.09	.04	.26	.10	.12	.08	.04	.02	.05
	Forks	column	.12	.24	.28	.06	.03	.05	.09	.02	.03	(a)	.04	.09
Wisc:	Green Bay	column	(a)	(a)	[c].04	[c].04	.04	.04	.04	.07	.03	(a)	(a)	.04

[a] Zero or trace.
[b] Data not available.
[c] Proportioned from originally consolidated data.

Table 2. Strontium-90 fallout in North and South America, HASL, January-December 1972

Sampling location		Type of collection	Deposition (nCi/m²)											
			Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Argentina:	Buenos Aires	column	0.03	0.13	0.09	0.03	0.02	0.05	0.04	0.06	0.07	0.03	0.06	0.08
	Formosa	column	.04	.05	.05	.02	.02	.04	.02	.03	.02	.03	.04	.02
	Malargue	column	.02	.06	.01	.02	.02	.02	.03	(a)	.03	.02	.07	(b)
Bahamas:	Bimini	column	(b)	(b)	(b)	.02	.03	.02	(a)	.05	(a)	(a)	(a)	(b)
Bermuda:	Kindley AFB	column	.02	.10	.11	.02	.05	.08	.02	.03	(a)	(a)	(a)	.01
Bolivia:	Chacaltaya	column	(a)	(a)	(a)	(a)	(a)	(a)	(a)	(a)	(a)	(a)	(a)	(a)
	La Paz (city)	column	.03	.01	(a)	(a)	(a)	(a)	(a)	.01	.01	(a)	(a)	(a)
	La Paz (Ovejuyo)	column	.02	(a)	(a)	(a)	(a)	(a)	(a)	(a)	.01	.02	(a)	(a)
Brazil:	Belem	column	.03	.04	.04	(a)	(a)	(a)	.03	(a)	(a)	.02	(a)	(a)
	Rio de Janeiro	column	[c].06	[c].06	[c].04	[c].05	[c].04	(b)	(b)	(b)	(b)	(b)	(b)	(b)
	Trinidade Island	column	(b)	(a)	.03	(b)	(b)	(b)	(b)	(b)	(b)	(b)	(b)	(b)
Canada:	Moosonee	column	.01	(a)	(a)	(a)	.05	.04	.09	.04	.02	.02	(a)	(a)
Canal Zone:	Balboa	column	(b)	(a)	(b)	.03	.02	.02	(a)	(a)	(a)	(b)	.01	.01
Chile:	Antofagasta	column	(b)	(b)	(a)	(a)	(a)	(a)	(a)	(b)	(b)	(b)	(b)	(b)
	Conception	column	(b)	(b)	(b)	(b)	(b)	(b)	(b)	(b)	(b)	(b)	.02	(a)
	Easter Island	column	.05	.04	.09	.02	.04	.06	.06	.03	.02	(a)	.02	.02
	Puerto Montt	column	.08	(b)	.13	.03	(b)	.07	.09	.10	(b)	(b)	(b)	.04
	Punta Arenas	column	(b)	.02	(a)	(a)	(b)	.01	.02	.02	.02	.02	(a)	(a)
	Santiago	pot	(a)	(a)	(b)	(b)	(b)	(b)	(b)	(b)	(b)	(b)	(b)	(b)
	Santiago	column	[c].01	[c].01	(a)	(a)	(b)	.12	.09	.09	.10	.04	(a)	(a)
Colombia:	Bogota	pot	(a)	(a)	(a)	(a)	(b)	(b)	(b)	(b)	(b)	(b)	(b)	(b)
Costa Rica:	Turrialba	column	.01	.05	.02	.04	(a)	.02	.02	(a)	(a)	(a)	(a)	.01
Equador:	Guayaquil	column	(b)	(b)	(b)	(b)	(b)	(b)	(b)	(b)	(b)	(b)	(b)	(b)
Greenland:	Thule	column	(a)	(a)	(a)	(a)	(a)	(a)	.02	.03	(a)	(a)	(a)	(a)
Iceland:	Keflavik	column	.05	(b)	.03	.04	.07	.06	.08	.05	.02	.02	(a)	(b)
Mexico:	Mexico City	column	(a)	(b)	(b)	.04	.04	.02	(a)	(a)	.02	(a)	(b)	(b)
Peru:	Lima	column	(a)	(a)	(a)	(a)	(a)	(a)	(a)	(a)	.02	(a)	(a)	(a)
Puerto Rico:	San Juan	column	.02	.03	.03	.02	.01	.03	(b)	.03	.02	(a)	(a)	.02
Venezuela:	Caracas (site 1)	column	(b)	(b)	.03	.02	(a)	(b)	(a)	(b)	.02	(a)	(a)	(a)

[a] Zero or trace.
[b] Data not available.
[c] Proportioned from originally consolidated data.

SECTION IV. OTHER DATA

This section presents results from routine sampling of biological materials and other media not reported in the previous sections. Included here are such data as those obtained from human bone sampling, Alaskan surveillance and environmental monitoring around nuclear facilities.

Environmental Levels of Radioactivity at Atomic Energy Commission Installations

The U.S. Atomic Energy Commission (AEC) receives from its contractors annual reports on the levels of environmental contaminants including radioactivity in the vicinity of major Commission installations. The reports include data from routine monitoring programs where operations are of such a nature that plant environmental surveys are required. From the complete environmental monitoring reports published in a compendium report entitled "Environmental Monitoring at Major U.S. Atomic Energy Commission Contractor Sites, Calendar year 1972," WASH 1259, those portions dealing with radioactivity are summarized for *Radiation Data and Reports*. Statements interpreting the radioactivity data are those of the USAEC contractors. The units for the data as reported in WASH-1259 have been converted from the format required by the AEC to that used by *Radiation Data and Reports*. The Environmental Protection Agency has not independently or critically reviewed the data or the conclusions derived therefrom.

Releases of radioactive materials from AEC installations are governed by radiation standards set forth by AEC's Division of Operational Safety in directives published in the "AEC Manual."[1]

Summaries of the environmental radioactivity data follow for Argonne National Laboratory, Bettis Atomic Power Laboratory, and the Paducah Plant.

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[1] Title 10, Code of Federal Regulations, Part 20, "Standards for Protection Against Radiation" contains essentially the standards published in Chapter 0524 of the AEC Manual.

1. Argonne National Laboratory[2]
January–December 1972

University of Chicago
Lemont, Ill.

Argonne National Laboratory (Illinois site) is located on a 3740-acre site in DuPage County, 27 miles southwest of downtown Chicago and 24 miles west of Lake Michigan. It lies south of Interstate Highway 55 and west of Illinois Highway 83. The terrain is rolling, partially-wooded, former prairie and farmland. The grounds contain a number of ponds and small streams, the principal one being Sawmill Creek, which runs through the site in a southerly direction and enters the Des Plaines River about 1.3 miles southeast of the center of the site. The land is drained primarily by Sawmill Creek, although the extreme southern portion drains directly into the Des Plaines River. This river flows southwest until it joins the Kankakee River about 30 miles southwest of the laboratory to form the Illinois River.

Argonne is a multidisciplinary research and development laboratory with two principal objectives: it carries out a broad program of basic research activities, and it serves as an important center for the design and development of nuclear reactors. Most of the basic research is concerned with the application of radiation as a tool in the physical and life sciences. The reactor effort is devoted largely to development of the liquid-metal-cooled fast-breeder power reactor. Almost all of the work at the laboratory is of an unclassified nature and deals with peacetime applications of nuclear energy.

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[2] Summarized from "Environmental Monitoring at Major U.S. Atomic Energy Commission Contractor Sites—Argonne National Laboratory Annual Report for 1972."

The principal nuclear facilities at the laboratory are a 5 MW heavy-water cooled and moderated general-purpose research reactor (CP-5) fueled with fully-enriched uranium; a 200 kW light-water cooled and moderated biological research reactor (JANUS) fueled with fully-enriched uranium; a 12.5 GeV proton accelerator, the Zero Gradient Synchrotron (ZGS); two critical assemblies, or zero power reactors (ZPR-6 and -9), that are fueled at various times with plutonium, uranium, or a combination of the two; a 60-inch cyclotron; several Van de Graaff accelerators; a fuel fabrication facility designed for plutonium usage; and several hot cells and laboratories designed for work with irradiated fuel elements and with multicurie quantities of the actinide elements.

The radioactivity of the environment was

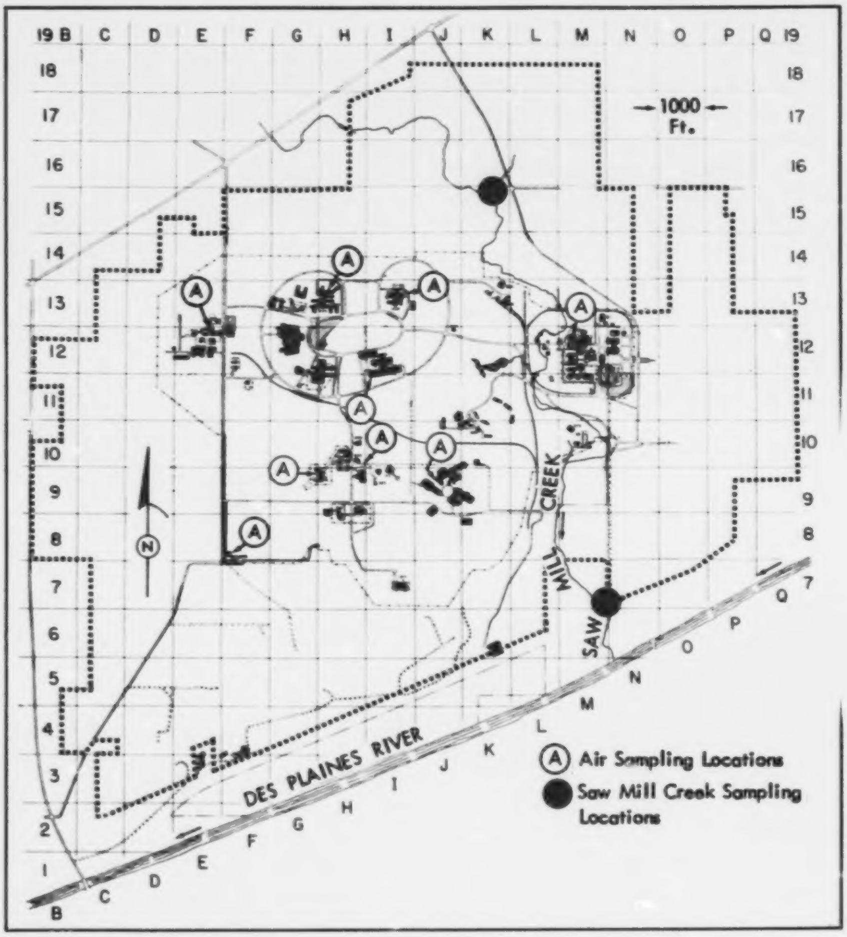

Figure 1. Onsite sampling locations at Argonne National Laboratory

determined by measuring the concentrations of radioactive nuclides in naturally-occurring materials and by measuring the external penetrating radiation dose. Sample collections and measurements were made both on and off the site for comparison purposes. Since radioactivity is usually spread by air and water, the sample collection program has concentrated on these media. In addition, soil, plants, milk, precipitation, animals, and material from the beds of lakes and streams were also collected and analyzed. The results included in this report are those that are pertinent to the evaluation of Argonne's contribution to the environmental radioactivity and to the differentiation of Argonne activity from fallout and other sources.

When a nuclide was not detected, the result is given as less than (<) the minimum amount detectable (detection limit) by the analytical method used. Averages including individual results that were less than the detection limit were calculated by one of the following two methods. If the bulk of the individual results was less than the detection limit, the average was calculated with the assumption that such results were equal to the detection limit, and the resulting average value is expressed as less than the computed average. If only a small fraction of the individual results were less than the detection limit, the average was calculated with the assumption that such results were actually one-half of the detection limit, and the average is given as a positive value. The averages that are obtained by using these two methods under the conditions indicated are believed to give an adequate picture of the true average activity at locations where the activity not only varied greatly, but at times was not detectable.

Average values are usually accompanied by a plus-or-minus (±) limit value. This value is the 95-percent confidence limit calculated from the standard deviation of the average and is a measure of the range in the activities encountered at that location. It does not represent the conventional error in the average of repeated measurements on the same or identical samples. Since many of the variations that occur in environmental radioactivity are not random but occur for specific reasons (e.g. nuclear testing), samples collected from the same location at different times are not replicates. The more random the variation in activity at a particular location, the closer the confidence limits will represent the actual distribution of values at that location. The averages and confidence limits should be interpreted with this in mind. When a ± figure accompanies an individual result in this report, it represents the statistical counting error at the 95-percent confidence level.

Where environmental quality standards have been established, the measured concentration or radiation dose is compared with the standard as a means of assessing its hazard. Unless otherwise specified, the standards used in this report are those given in AEC Manual Chapter 0524.

Radioactivity in air

The radioactivity of particulate matter in air was determined by drawing air through filter paper at a known rate and measuring the radioactivity of the particles collected by the paper. Samples were collected continuously, except for occasional equipment failures, at nine locations on the Argonne site and at six locations off the site. The sampling locations are shown in figures 1 and 2. At one location on

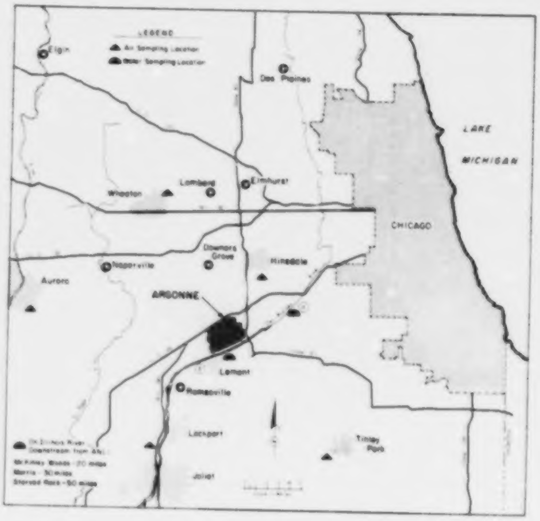

Figure 2. Location of Argonne National Laboratory (including some offsite sampling locations)

the site, the filter paper was changed daily; at all other locations, the filter papers were changed at weekly intervals. The daily samples record short-term changes in radioactivity, while the weekly samples are used to compare onsite and offsite activities. Higher activities on the site are indicative of radioactivity released by Argonne if the differences are greater than the error in sampling and counting. This error is between 5 and 20 percent for most results, but approaches 100 percent at the detection limit.

The total alpha and beta radioactivities in the weekly samples are given in table 1. The alpha and beta radioactivities were measured in low-background gas-flow proportional counters, and the counting efficiencies used to convert counting rates to disintegration rates were those measured for radon decay products on filter paper. The average concentrations of a number of gamma-ray emitters, as determined by gamma-ray spectrometry performed on composite weekly samples, are given in table 2. The gamma-ray measurements were made with a spectrometer that used a shielded 35 cm^3 lithium-drifted germanium diode as the detector. The detector was calibrated for each gamma-emitting radionuclide given in table 2.

The activities were very similar on and off the site and no significant differences between the locations were found. This indicates that Argonne did not add detectably to the average airborne particulate activity of the environment during the year, and that the activities originated in widespread sources (such as fallout from nuclear test detonations and naturally-occurring materials) and not in localized sources (such as the laboratory).

Table 1. Alpha and beta radioactivity in air-filter samples,[a] Argonne National Laboratory, 1972

Month	Location	Number of samples	Alpha radioactivity (fCi/m^3) Maximum	Alpha Minimum	Alpha Average	Beta radioactivity (pCi/m^3) Maximum	Beta Minimum	Beta Average
January	Onsite	40	3.4	1.0	2.3	0.26	0.042	0.11
	Offsite	22	6.1	.8	2.6	.22	.023	.13
February	Onsite	32	4.0	1.3	2.4	.13	.062	.087
	Offsite	21	12.5	1.3	3.4	.23	.041	.095
March	Onsite	34	3.2	.9	2.2	.10	.046	.075
	Offsite	26	8.2	1.3	2.8	.11	.035	.078
April	Onsite	34	4.5	1.3	2.7	.32	.045	.094
	Offsite	21	4.8	1.5	2.6	.37	.058	.094
May	Onsite	35	7.0	2.1	3.5	.67	.086	.21
	Offsite	23	6.1	1.7	3.3	.60	.065	.23
June	Onsite	34	8.0	1.0	3.1	.44	.11	.21
	Offsite	22	5.1	1.2	2.6	.30	.11	.18
July	Onsite	37	6.8	1.1	3.2	.30	.060	.14
	Offsite	23	3.8	1.1	2.5	.27	.069	.14
August	Onsite	32	4.1	.6	2.1	.12	.042	.072
	Offsite	25	3.1	.9	1.9	.16	.048	.073
September	Onsite	37	3.6	.7	1.9	.089	.026	.050
	Offsite	24	3.0	.8	1.8	.082	.022	.048
October	Onsite	37	4.1	.7	1.9	.074	.017	.036
	Offsite	26	4.4	.9	2.1	.066	.023	.036
November	Onsite	35	7.3	.3	1.6	.072	.014	.032
	Offsite	22	5.6	.9	1.8	.054	.017	.028
December	Onsite	34	4.3	.3	1.9	.28	.023	.046
	Offsite	24	4.4	.7	2.1	.065	.023	.040
Annual summary	Onsite	421	8.0	0.3	2.4 ± 0.3	0.67	0.014	0.097 ± 0.035
	Offsite	279	12.5	0.7	2.5 ± 0.3	0.60	0.017	0.098 ± 0.036

[a] These results were obtained by measuring the samples 4 days after they were collected in order to avoid counting the natural radioactivity due to radon and thoron decay products. This activity is normally present in the air and disappears within 4 days by radioactive decay.

Table 2. Gamma-ray radioactivity in air-filter samples, Argonne National Laboratory, 1972

Radionuclide	Location	Concentration (fCi/m³)												
		Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual average
Antimony-125	Onsite	1	<1	1	1	2	2	1	<1	<1	<1	<1	<1	1± 1
	Offsite	1	<1	1	1	2	2	1	<1	<1	<1	<1	<1	1± 1
Barium-lanthanum-140	Onsite	6	4	1	2	4	2	1	<1	<1	<1	<1	<1	2± 4
	Offsite	6	3	1	2	4	2	1	<1	<1	<1	<1	<1	2± 4
Beryllium-7	Onsite	70	81	116	103	150	140	105	85	95	91	67	85	99±54
	Offsite	70	74	108	105	158	120	97	80	88	87	66	81	95±52
Cerium-141	Onsite	2	2	1	2	10	10	6	2	1	<1	<1	<1	3± 7
	Offsite	3	2	1	1	10	9	6	2	1	<1	<1	<1	3± 6
Cerium-144	Onsite	10	10	13	11	23	23	14	7	6	3	2	2	10±13
	Offsite	9	9	14	12	22	20	14	6	5	3	2	2	10±12
Cesium-137	Onsite	1	2	2	2	3	3	2	1	1	1	<1	<1	2± 2
	Offsite	1	1	2	2	3	3	2	1	1	1	<1	<1	2± 2
Cobalt-60	Onsite	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
	Offsite	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Iodine-131	Onsite	50	10	<10	10	10	<10	<10	<10	<10	<10	<10	<10	10±35
	Offsite	60	10	10	10	10	<10	<10	<10	<10	<10	<10	<10	11±32
Manganese-54	Onsite	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
	Offsite	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Ruthenium-103	Onsite	4	4	1	2	16	20	15	5	3	1	<1	<1	6±12
	Offsite	5	4	2	2	15	18	14	4	3	1	<1	<1	6±11
Ruthenium-rhodium-106	Onsite	3	5	6	5	11	12	8	3	2	<1	<1	<1	5± 7
	Offsite	3	3	6	4	9	10	7	3	2	<1	<1	<1	4± 6
Zirconium-niobium-95	Onsite	6	6	5	6	45	55	35	15	8	3	1	2	16±35
	Offsite	5	4	4	5	45	46	32	11	6	4	2	2	14±31

The alpha radioactivities averaged 25 percent lower than 1971, but were still in their normal range. The alpha emitters in the air samples are principally naturally-occurring radionuclides. About two-thirds of the gamma activity and a smaller fraction of the beta radioactivity was due to beryllium-7, produced in the stratosphere by cosmic-ray interactions. Most of the remaining beta and gamma activity was due to fission and neutron activation products from nuclear test detonations. Except for the short-lived fission products, the activities, including the naturally-occurring beryllium-7, increased in concentration from January to May, then generally decreased during the remainder of the year. This variation can be attributed to the usual "spring maximum" in the stratospheric fallout rate. The fact that the concentrations of the longer-lived fission products varied in approximately the same manner as beryllium-7 (except that they decreased at a greater rate during the latter part of the year through radioactive decay and fallout, since, unlike beryllium-7, they are not produced continuously) is evidence that the bulk of the fission products was also derived from the stratosphere.

The detection of short-lived fission products (iodine-131 and barium-140) at all sampling locations during the last quarter of 1971 and the first half of 1972, indicates the presence of fallout from a series of tests conducted during this period. The increase in 40-day half-life ruthenium-103, 65-day half-life zirconium-95, and 32-day half-life cerium-141 in the spring implies a recent injection of fission products into the atmosphere at high altitudes. The variations with time in the concentrations of the short-lived fission products correlate with the dates of announced nuclear tests.

The average beta radioactivity for the year, 0.1 pCi/m^3, was about 3 times lower than in 1971. This was principally due to substantial decreases in the concentration of intermediate half-life fission products: cerium-144, ruthenium-106, and zirconium-95. The decreases are greater than can be accounted for on the basis of radioactive decay. Since the levels of beryllium-7 have been constant over the past years, these lower concentrations indicate a depletion of fission products in the stratospheric reservoir. The results obtained for the air filter samples are further summarized in table 3 in order to compare the average concentrations with the concentration guides. Regardless of source, all concentrations were well below the AEC standard.

Table 3. Average particulate radioactivity in air-filter samples, ANL, 1972

Radionuclide	Detection limit [a] (pCi/m^3)	AEC standard [a] (pCi/m^3)	Concentration (pCi/m^3)	Percent of AEC standard
Antimony-125	0.001	900	0.001	0.0001
Barium-lanthanum-140	.001	1 000	.002	.0002
Beryllium-7	.001	40 000	.099	[b] .0002
Cerium-141	.001	5 000	.003	.00006
Cerium-144	.001	200	.010	.005
Cesium-137	.001	500	.002	.0004
Cobalt-60	.001	300	<.001	<.0003
Iodine-131	.01	100	.010	.010
Manganese-54	.001	1 000	<.001	<.0001
Ruthenium-103	.001	3 000	.006	.0002
Ruthenium-rhodium-106	.001	200	.005	.003
Zirconium-niobium-95	.001	1 000	.016	.002
Alpha	.0002	10	.0024	[b] .024
Beta	.0005	10	.097	.97

[a] The AEC standards are those given in US AEC Manual Chapter 0524 for uncontrolled areas.

[b] This radioactivity is due to naturally occurring radionuclides.

Air was sampled continuously for radioiodine with activated charcoal in the 200 and 300 Areas because of the possibility of iodine releases in these areas. Very small amounts of iodine-131, up to 0.15 pCi/m^3 (0.15 percent of the uncontrolled AEC standard), were detected in January and February and were probably produced in nuclear tests conducted late in 1971, along with the other short-lived fission products found in the air filter samples. No iodine radioactivity was detected at any other time during the year at either location.

Air sampling for plutonium was begun in March in the northeast area of the site (12N, figure 1) and in October at 10H in the 300 Area close to the center of plutonium usage on the site. Offsite sampling for plutonium will be initiated early in 1973. Monthly samples were collected on a polystyrene filter medium at flow rates of 35 or 85 m^3/h, depending on the sampler. The total air volume filtered for each sample was about 30 000 and 65 000 m^3, respectively. Samples were ignited at 600°C to remove organic matter and prepared for plutonium analysis by vigorous treatment with hot hydrochloric, hydrofluoric, and nitric acids.

This treatment has been found in our laboratory to solubilize plutonium that has been ignited at 1000°C. The plutonium was separated from nitric acid solution on an anion-exchange column, electrodeposited, and its composition determined by alpha spectrometry. Alpha spectrometry cannot distinguish between plutonium-239 and -240, and although in the following discussion, and in the tables, only plutonium-239 is mentioned, it should be understood that the alpha radioactivity due to the less abundant plutonium-240 isotope is also included. The chemical recovery was determined by adding a known amount of plutonium-236 tracer to the sample before ignition. The chemical separation procedure also yields a separated thorium fraction, and this fraction was also electrodeposited and measured in an alpha spectrometer beginning with the June samples. To obtain the thorium recovery for these samples, thorium-234 was added prior to ignition. An aliquot of the sample solution was also analyzed for uranium by a standard type of fluorophotometric procedure. The uranium concentrations are obtained in mass units by this technique. Since the uranium is believed to have the normal isotopic composition, the results were converted to activity units for comparison purposes by use of the specific activity of natural uranium, 675 nCi/g. The results are given in table 4.

The plutonium concentrations show the same general monthly variation discussed earlier for gamma-ray emitters (table 2). The concentrations are also similar to those reported by other investigators (*1–2*) for samples collected at similar latitudes, but away from nuclear installations.[3] The monthly variations and the similarities between the samples collected by other laboratories indicate that the plutonium in the samples on the Argonne site is primarily from fallout. The October 10H concentration (41 aCi/m³), although within the yearly range, does not follow the monthly trend. The reason for this discrepancy is not clear, although at least two possibilities exist. The concentrations of the thorium isotopes are similar in most samples, about 20 aCi/m³ for thorium-232 and thorium-228 and about 30 aCi/m³ for thorium-230. The October 10H sample was in this range, while the October 12N sample, for some reason, filtered relatively few particles and therefore the plutonium concentrations in the air were actually about four times greater than found at 12N. This implies, incidentally, that the

Table 4. Plutonium, thorium, and uranium concentrations in air-filter samples, ANL, 1972

Month	Location	Concentrations (aCi/m³)					
		Plutonium-239	Plutonium-238	Thorium-232 [a]	Thorium-228	Thorium-230	Uranium [a]
March	12N	31 ±3	3.3 ±1.0				
April	12N	33 ±3	4.2 ±1.5				316 ±41
May	12N	41 ±3					146 ± 9
June	12N	45 ±3	2.9 ± .9	20 ±1	26 ±1	33 ± 2	90 ± 8
July	12N	32 ±3	1.5 ± .8	75 ±2	75 ±2	113 ± 3	77 ± 4
August	12N	28 ±2	1.2 ± .8	23 ±2	28 ±3	36 ± 3	121 ±28
September	12N	17 ±2	1.5 ±1.1	20 ±2	16 ±3	27 ± 3	63 ± 9
October	12N	7.6 ±3.0	<1	4.8 ±1.8	4.1 ±1.5	12 ± 3	40 ± 8
	10H	41 ±3	2.5 ±1.2	24 ±3	20 ±3	42 ± 2	79 ±14
November	12N	6.6 ±3.3		15 ±2	20 ±3	29 ± 3	89 ±13
	10H	7.8 ±2.0		20 ±2	28 ±2	36 ± 2	65 ±18
December	12N	11.2 ±1.4	2.4 ± .9	18 ±2	23 ±3	40 ± 3	125 ±30
	10H	9.1 ± .8	1.2 ± .4	26 ±2	21 ±2	48 ± 2	83 ±29
Monthly average		27 ±9	[illegible] ± .7	27 ±15	29 ±15	45 ±23	118 ±52
Percent AEC standard		.003	.0002	(.003)	(.015)	(.015)	(.003)
AEC standard		1×10⁶	1×10⁶	1×10⁶	2×10⁵	3×10⁵	4×10⁶
Detection limit		1	1	1	1	1	20

[a] The concentrations in units of pg/m³ can be obtained by multiplying the value in aCi/m³ by 1.48 for uranium and by 9 for thorium-232. The amounts of the other two thorium isotopes in mass units are negligible in comparison to thorium-232. The average thorium and uranium concentrations are 240 pg/m³ and 170 pg/m³, respectively.

[b] Parentheses indicate that the radioactivity is due to the naturally-occurring radionuclide.

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[3] E. P. Hardy, Jr., USAEC Health and Safety Laboratory, personal communication (February 20, 1973).

plutonium fallout rate was unusually high during October. A second possibility is that the plutonium-239 fallout was actually closer to 8 aCi/m^3 than 40 aCi/m^3, and that the additional plutonium, about 30 aCi/m^3 was due to plutonium from Argonne. An explosion involving plutonium occurred in Building 205 (location 12H), north of the 12N sampler on October 17, 1972, when the wind was from the north-northwest (330°), but was relatively calm (about 3–4 mph at the 19 foot level and about 6 mph at the 150 foot level). However, there is no unequivocal corroborating evidence that any plutonium escaped from Building 205 since, as will be seen, soil samples collected downwind from the building did not confirm a release. From whatever sources, the total plutonium-239 concentration, 41 aCi/m^3, was very low compared to the exposure standards, 0.004 percent of the AEC standard for uncontrolled areas and 0.0001 percent of the AEC standards for controlled areas.

The thorium and uranium concentrations given in table 4 are considered to be of natural origin. There is no indication that any of these elements in the air samples originated at Argonne. The percent of AEC standards for these activities is included for purposes of completeness.

Air sampling for argon-41, a beta emitter with a 1.8 hour half-life that is produced in an operating reactor by neutron irradiation of the stable argon in air, was conducted near the CP-5 reactor (Building 330, 9H, figure 1). Samples were collected by filling out an evacuated "Marinelli type" container once a day from 2 to 5 times during each week of reactor operation and the argon-41 measured by gamma-ray spectrometry. Each sampling consisted of two "grab" samples, one taken 45 meters east of the reactor and one downwind from the reactor at a point favorable for detection of argon-41. The results are given in table 5. Because of the timing and location of the sample collection, the actual average concentration in the vicinity of the reactor was less than the values in the table. The average and maximum concentrations of 0.12 and 1.2 μCi/m^3 are, respectively, about 3 and 30 times the AEC standard for uncontrolled areas and 0.060 and 0.6 times the AEC standard for controlled areas. In this case, comparison with the AEC standard for controlled areas is more appropriate since the sampling is conducted on the site and the argon-41 originated in the reactor. At the site security fence, the closest uncontrolled approach to the laboratory, the concentrations were less than the detection limit, 20 nCi/m^3. Based on penetrating radiation measurements, the concentration at the fence averaged less than 800 pCi/m^3, the concentration that would give a dose of 10 mrem/year.

Tritium (tritiated) water vapor in the air was monitored on and off the site because substantial amounts are in use at the laboratory. Water vapor was removed from the air by absorption on silica gel and the tritium measured by counting the water in a liquid scintilla-

Table 5. Argon-41 concentrations in air, 300 Area, ANL, 1972

Month	Number of samples	Concentration (nCi/m^3)			Percent of AEC standard [a]		
		Maximum	Minimum	Average	Maximum	Minimum	Average
January	16	335	<20	56	17	<1	3
February	18	1 160	<20	100	58	<1	5
March	12	1 160	<20	180	58	<1	9
April	16	1 000	<20	180	50	<1	9
May	14	500	<20	125	25	<1	6
June	16	420	<20	82	21	<1	4
July	16	950	<20	140	48	<1	7
August	8	220	<20	81	11	<1	4
September	16	1 160	<20	120	58	<1	6
October	12	695	<20	150	35	<1	8
November	16	430	<20	73	22	<1	4
December	16	815	<20	160	41	<1	8
Annual summary	176	1 160	<20	121 ± 25	58	<1	6

[a] This is the AEC standard for controlled areas.

Table 6. Tritium concentrations in air, 300 Area, ANL, 1972

Month	Number of samples	Concentration (pCi/m³)			Percent of AEC standard [a]		
		Maximum	Minimum	Average	Maximum	Minimum	Average
January	8	880	1.5	210	0.44	0.00075	0.10
February	8	587	11.6	146	.29	.0058	.073
March	16	781	.94	117	.39	.00047	.058
April	18	274	4.3	99	.14	.0022	.050
May	18	1 121	3.4	145	.56	.0017	.072
June	14	718	6.1	194	.36	.0030	.097
July	9	260	18.5	126	.13	.0092	.063
August	9	367	86.0	166	.18	.043	.083
September	9	178	24.3	78	.089	.012	.039
October	9	497	8.7	117	.25	.0043	.058
November	7	389	11.4	114	.19	.0057	.057
December	9	357	30.7	115	.18	.015	.076
Annual summary	134	1 121	0.94	139 ± 22	0.56	0.00047	0.070

[a] This is the AEC standard for uncontrolled areas.

ion counter. Tritium is produced continuously in an operating reactor by several methods. In CP-5, the largest source is by neutron irradiation of the heavy water used for cooling and neutron moderating. Air was sampled continuously for tritiated water vapor at a permanent station 45 meters east of the CP-5 reactor, and during the first half of the year, 180 meters from the reactor in various directions. The results, given in table 6, were all positive, although the concentrations were well below the AEC standard. In the uncontrolled area, AEC standards are shown in table 6 to allow easy comparison with the offsite concentrations discussed below. As in the case of argon-41 near the reactor, application of the AEC standard for controlled areas is appropriate. The percent of AEC standard for controlled areas is 25 times less than the values in table 6. As will be seen, normal or background tritium concentrations in air during 1972 ranged from 0.2 to 8.6 pCi/m³ and averaged about 2.4 pCi/m³. Near CP-5, the average was 140 pCi/m³ and the difference was due to tritium that left the reactor building. The average concentration near the reactor was almost 3 times lower than in 1971 because a leak that developed in the heat exchanger last year was repaired.

As an extension of a study begun in 1971, air was also sampled for tritiated water vapor at two site security fence locations, 590 meters directly west (10E) and 480 meters directly south (8H) of the reactor. These two locations are the closest uncontrolled approaches to CP-5. Samples were also collected once a month at an onsite location in the East Area, 1800 meters northeast of the CP-5 reactor and offsite at a location approximately 9.6 km northwest of the laboratory. The results are given in table 7. The fence line results show good correlation with wind direction and indicate that dilution to background levels occurs within 450–550 meters of the reactor in directions other than that from which the wind is blowing. The average and maximum concentrations were equivalent to 0.008 and 0.05 percent of the AEC standard, respectively. The average fence line concentration corresponds to a dose of 0.038 mrem/year, about 85 percent from Argonne operations and the remainder from weapons testing.

The higher concentrations in the east area compared to offsite concentrations may also be attributed to CP-5. Measurements from previous years show that when the wind was from the southwest and the tritium concentration near the reactor was sufficiently high, measurable increases above the normal background level can be observed.

The offsite concentrations, which may be considered as normal for this area, decreased by a factor of two over the 1971 values. Most of this tritium was produced in nuclear test detonations, and a decrease is expected, since few atmospheric tests were conducted in 1971 and 1972. Much of the test-produced tritium has been transported from the atmosphere to the hydrosphere.

Table 7. Tritium concentrations in air, Argonne National Laboratory, 1972

Month	Location	Number of samples	Concentration (pCi/m³)			Percent of AEC standard *		
			Maximum	Minimum	Average	Maximum	Minimum	Average
January	East area	1	2.6			0.0013		
	Offsite	1	.68			.00034		
February	East area	1	11.0			.0055		
	Offsite	1	.87			.00043		
March	East area	1	.43			.00022		
	Offsite	1	.18			.00009		
April	East area	1	2.2			.0011		
	Offsite	1	1.6			.00080		
May	East area	1	2.7			.0013		
	Offsite	1	2.9			.0014		
June	South fence (8H)	2	56.7	13.7	35.2	.028	0.0068	0.018
	East area	1	6.1			.0030		
	Offsite	1	8.6			.0043		
July	South fence (8H)	9	13.2	2.5	8.4	.0066	.0012	0.0042
	East area	1	14.7			.0074		
	Offsite	1	6.5			.0032		
August	West fence (10E)	9	8.1	2.8	5.8	.0040	.0014	.0029
	East area	1	3.9			.0020		
	Offsite	1	2.5			.0013		
September	South fence (8H)	9	55.6	.77	13.5	.028	.00038	.0068
	East area	1	5.4			.0027		
	Offsite	1	2.5			.0013		
October	South fence (8H)	9	96.0	.33	26.7	.048	.00016	.013
	East area	1	3.5			.0017		
	Offsite	1	.89			.00044		
November	South fence (8H)	7	59.0	.29	16.0	.029	.00014	.0080
	East area	1	2.3			.0011		
	Offsite	1	.84			.00041		
December	West fence (10E)	9	3.7	.82	1.8	.0019	.00041	.00088
	East area	1	2.4			.0012		
	Offsite	1	.38			.00019		
Annual summary	Fence line	54	96.0	0.29	15.3±9.0	0.048	0.00014	0.0076
	East area	12	14.7	0.43	4.8±2.4	0.0074	0.00022	0.0024
	Offsite	12	8.6	0.18	2.4±1.5	0.0043	0.00009	0.0012

* This is the AEC standard for uncontrolled areas.

Radioactivity in surface water

Total (nonvolatile) alpha and beta radioactivities were determined by counting the residue remaining after evaporation of the water, and applying counting efficiency corrections determined for uranium-233 (for alpha radioactivity) and thallium-204 (for beta radioactivity), respectively, to obtain disintegration rates. Tritium was determined by liquid scintillation counting of a separate sample, and this activity does not appear in the total beta radioactivity. Uranium was determined fluorophotometrically, and the results calculated in terms of activity, assuming the isotopic composition of natural uranium. Analyses for other radionuclides were performed by specific radiochemical separations followed by appropriate counting. One-liter aliquots were used for all analyses except tritium and plutonium-neptunium. Most tritium analyses were performed by counting 10 ml in a gel system. A few samples were analyzed by electrolytic enrichment of 250 ml aliquots prior to counting. Plutonium and neptunium analyses were performed on 10-liter samples by a plutonium chemical separation method (*3*), modified to include neptunium, followed by alpha spectrometry. Plutonium-236 was used to determine the plutonium yield.

Argonne wastewater is discharged into Sawmill Creek, a small stream that runs through the laboratory grounds, drains surface water from much of the site, and flows into the Des Plaines River about 450 meters downstream from the wastewater outfall. Sawmill Creek was sampled upstream from the Argonne site and downstream from the wastewater outfall to determine if radioactivity was added to the stream in Argonne wastewater or from surface drainage. The sampling locations are shown in figure 1. Below the wastewater outfall, the creek was sampled continuously, and the individual samples collected five times weekly. Since it was impractical to analyze all the samples for all the nuclides and elements desired, equal portions of the samples collected each week were combined and analyzed. The results obtained in this way represent the average concentrations in the weekly samples. Above the site, samples were collected twice a month and selected samples were analyzed for the same radionuclides as the below-outfall samples.

Annual summaries of the results obtained for Sawmill Creek are given in table 8. Comparison of the results, and 95-percent confidence limits of the averages, for the two sampling locations show that the only nuclides whose presence in the creek water can be attributed to Argonne operations were tritium, neptunium-237, plutonium-239, and possibly strontium-90. The fraction of individual samples containing activity attributable to Argonne was 90 percent for tritium and 50 percent for plutonium and neptunium. The concentrations of all four nuclides were quite low compared to the AEC standards. The principal radionuclide added to the creek by Argonne wastewater, in terms of both concentration and percent of AEC standard, was tritium. The average Argonne contribution of this nuclide to the creek amounted to only 0.02 percent of the AEC standard and the highest concentration in any single sample was equivalent to 0.02 percent of the AEC standard and the highest concentration in any single sample was equivalent to 0.06 percent of the AEC standard. The average tritiated water concentration in Sawmill Creek during the past few years shows Argonne's tritium contribution to have decreased by a factor of three over 1970 and by a factor of 20 over 1971, when a leak occurred in the CP-5 heat-exchanger. This is evidence of the laboratory's continuing effort to reduce emissions to the lowest possible levels. The tritium in the creek above the site (270 pCi/liter) was similar in concentration to levels found away from the laboratory site and is characteristic of the pres-

Table 8. Radioactivity in Sawmill Creek water, Argonne National Laboratory, 1972

Radionuclide	Location	Number of samples	Concentration (pCi/liter)			Percent of AEC standard		
			Maximum	Minimum	Average	Maximum	Minimum	Average
Alpha (nonvolatile)	Upstream	24	2.8	1.1	2.0 ±0.18	(0.093)	(0.037)	(0.067)
	Downstream	253	3.8	0.64	1.6 ± .16	(.13)	(.021)	(.053)
Beta (nonvolatile)	Upstream	24	33	8.4	17 ±2.3	(1.1)	(.28)	(.57)
	Downstream	253	44	6.7	16 ±1.5	(1.5)	(.22)	(.53)
Tritium	Upstream	23	470	<200	270 ±45	.016	<.0067	.0090
	Downstream	253	1 870	205	565 ±70	.062	.0068	.019
Strontium-89	Upstream	10	<2			<.07		
	Downstream	200	<2			<.07		
Strontium-90	Upstream	10	1.4	<.5	.76 ± .25	.47	<.17	.25
	Downstream	200	2.0	<.5	1.1 ± .13	.67	<.17	.37
Iodine-131	Upstream	7	7.6	<3	<3.7	2.5	<1	<1.2
	Downstream	169	<3			<1		
Barium-140	Upstream	9	<2			<.007		
	Downstream	169	<2			<.007		
Uranium (natural)[a]	Upstream	13	2.4	.96	1.6 ± .21	(.0060)	(.0024)	(.0040)
	Downstream	253	2.7	.95	1.6 ± .14	(.0068)	(.0024)	(.0040)
Neptunium-237	Upstream	11	<.002			<.00007		
	Downstream	253	.15	<.002	.011 ± .0064	.005	<.00007	.00037
Plutonium-239	Upstream	11	<.0005			<.00001		
	Downstream	253	.035	<.0005	.0015 ± .0013	.00070	<.00001	.000030

[a] Uranium concentration in units of μg/liter can be obtained by multiplying the concentration given by 1.48 pCi/liter. The average concentration in the Creek then becomes 2.4 μg/liter.

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ent normal levels of tritium in surface waters. During 1972, the tritium content of several Lake Michigan water samples was 275 to 280 pCi/liter. Over the past 2 years, the tritium concentration in surface water samples has decreased by a factor of 2 as the tritium from nuclear tests mixed with and was diluted by the hydrosphere.

The average total alpha and beta radioactivities were higher above the site, indicating that at times Argonne wastewater contained less nonvolatile activity than creek water. The higher activities above the site are probably due to the water added to the creek by a large municipal sewage treatment plant. The large amount of dissolved solids added in the sewage water is accompanied by a small amount of radioactive nuclides, and increases the radioactivity in natural creek water. The total alpha and beta radioactivities were not appreciably different than in 1971.

In addition to the natural beta radioactivity and that added by wastewater below the outfall, beta radioactivity from nuclear detonations was detected at both sampling locations. The normal nonvolatile beta radioactivity is approximately 10 pCi/liter. It is estimated that fallout activity added about 5 pCi/liter to the nonvolatile beta activity at both locations and that the Argonne contribution below the outfall averaged about 1 pCi/liter equivalent to 0.03 percent of the AEC standard. The Argonne contribution remained the same as 1971 levels, while the fallout contribution decreased by about a factor of 2.

The same nuclides added to the creek in Argonne wastewater are also produced in nuclear detonations and are constituents of fallout (although some are not present in amounts above the detection limits). The total concentration, regardless of source, must be used in assessing the health hazard of a radionuclide not naturally present, and the percent of the AEC standards for all nuclides listed in table 8 were very low.

Since Sawmill Creek empties into the Des Plaines River, which in turn flows into the Illinois River, the radioactivity in the latter two streams is important in assessing the contribution of Argonne wastewater to the environmental radioactivity. The Des Plaines River was usually sampled twice a month below and monthly above the mouth of Sawmill Creek to determine if the radioactivity in the creek had

Table 9. Radioactivity in Des Plaines River water, Argonne National Laboratory, 1972

Radionuclide	Location	Number of samples	Concentration (pCi/liter)			Percent of AEC standard		
			Maximum	Minimum	Average	Maximum	Minimum	Average
Alpha (nonvolatile)	Upstream	11	3.4	0.82	1.8 ± 0.39	(0.11)	(0.027)	(0.060)
	Downstream	24	3.1	.85	1.8 ± 0.22	(.10)	(.028)	(.060)
Beta (nonvolatile)	Upstream	11	43	5.1	13 ± 6.2	(1.4)	(.17)	(.43)
	Downstream	24	24	4.9	11 ± 2.0	(.80)	(.16)	(.37)
Tritium	Upstream	11	352	<200	245 ±45	.012	<.0067	.0082
	Downstream	24	378	<200	230 ±35	.013	<.0067	.0077
Strontium-89	Upstream	9	<2			.07		
	Downstream	17	<2			.07		
Strontium-90	Upstream	9	1.6	<.5	1.1 ± .29	.53	<.17	.37
	Downstream	17	2.0	.50	1.2 ± .22	.67	.17	.40
Iodine-131	Upstream	7	<3			<1		
	Downstream	14	3.0	<3	<3	1.0	<1	<1
Barium-140	Upstream	8	<2			<.007		
	Downstream	15	<2			<.007		
Uranium (natural)*	Upstream	10	2.1	.95	1.6 ± .21	(.0052)	(.0024)	(.0040)
	Downstream	23	3.1	.40	1.6 ± .27	(.0078)	(.0010)	(.0040)
Neptunium-237	Upstream	11	<.002			<.00007		
	Downstream	10	<.002			<.00007		
Plutonium-239	Upstream	11	.0014	<.0005	.00072 ± .00027	.000028	<.00001	.000014
	Downstream	10	.00092	<.0005	.00055 ± .00017	.000018	<.00001	.000011

* Uranium concentrations in units of μg/liter can be obtained by multiplying the concentration given by 1.48. The average concentration is 2.4 μg/liter.

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any effect on the activity in the river. Annual summaries of the results obtained for these two locations are given in table 9. The concentrations were in their normal ranges. The natural nonvolatile beta activity in the river is 5 to 10 pCi/liter, and the excess, 4 to 5 pCi/liter was due to fallout.

Evidence of fission product fallout is apparent in some of the water samples. Positive iodine-131 concentration in the Des Plaines River and at 15K in Sawmill Creek on the same day in early May correlate with air filter results that indicated a recent atmospheric nuclear test. Between June and October, plutonium-239 was detected at both locations in the river. Since the river consists mainly of surface runoff water, the presence of the plutonium-239 can be attributed to fallout, carried down by the rains and collected in the river. The fact that plutonium-239 could not be found at any time in Sawmill Creek above the site is due to the fact that a substantial portion of this water is from deep municipal wells.

The activities in samples of Illinois River water (table 10) were similar to those found in other bodies of water in the area and to the activities found previously at these same locations. The average alpha concentration of 1.2 pCi/liter and average beta concentration of 8.5 pCi/liter of 31 offsite surface water samples collected during the year is evidence that the Illinois River activity levels are normal. No radioactivity originating at Argonne could be detected in the Des Plaines or Illinois Rivers.

Soil, grass, and benthic materials

Plutonium deposition in soil, grass, and benthic materials was measured on and off the site to study the plutonium fallout level in the area from nuclear testing and to determine if any plutonium is present in the environment that might be due to Argonne operations. Soil samples consisted of a core 173 cm^2 in area of 30 cm deep. The grass samples were obtained by collecting all the grass from a 1 m^2 area. A grab sampling technique was used to obtain benthic materials. After drying, grinding, and mixing, 100 gram portions of soil and benthos were analyzed. The size of the grass samples was 40 g of the oven-dried plant.

The onsite and offsite soil results are given in tables 11 and 12, respectively. The limits given for the individual results are the statistical counting errors at the 95-percent confidence level, while the limits of the averages are the 95-percent confidence levels calculated from the standard deviation of the average. Comparison of the onsite and offsite samples shows that the same average and general range of concentrations exist in all areas for both plutonium isotopes, and it may be concluded that the plutonium in the onsite samples resulted primarily from fallout of debris from nuclear detonations. Fallout deposition values found by other laboratories (*4–6*) are in the same range as those reported here, namely about 2 nCi/m^2.

Several onsite locations are slightly higher than the highest offsite sample. These samples

Table 10. Radioactivity in Illinois River water, ANL, 1972

Location	Date collected	Concentration (pCi/liter)					
		Alpha (nonvolatile)	Beta (nonvolatile)	Tritium	Uranium [a]	Neptunium-237	Plutonium-239
McKinley Woods State Park	June 27	1.2	9.7	390	0.61	<0.001	<0.0005
Below Dresden Power Station	June 27	1.2	7.4	285	1.1	<.001	<.0005
Morris	June 27	1.0	8.2	315	.68	----------	----------
McKinley Woods State Park	October 5	1.1	8.4	290	1.5	<.0005	[b].00053
Below Dresden Power Station	October 5	.57	5.3	290	1.1	<.0005	[b].00022
Morris	October 5	.32	6.6	280	1.0	----------	----------
Starved Rock State Park	October 5	.70	6.6	245	1.3	----------	----------

[a] Uranium concentrations in units of μg/liter can be obtained by multiplying the concentration given by 1.48.
[b] These analyses were made on a 45-liter sample; all other plutonium analyses were made on 10-liter samples.

Table 11. Plutonium concentrations in onsite soil, ANL, 1972

Date collected	Location [a]	Plutonium-238		Plutonium-239		^{238}Pu/^{239}Pu
		(fCi/g)	(nCi/m^2)	(fCi/g)	(nCi/m^2)	
June 7:	12L	0.34 ±0.24	0.13 ±0.086	4.5 ±0.5	1.74 ±0.20	0.075
	12L	.61 ± .48	.26 ± .20	6.7 ±1.1	2.84 ± .47	.092
	12L	.79 ± .30	.24 ± .088	5.6 ± .6	1.70 ± .18	.14
	12L	.51 ± .24	.23 ± .10	3.9 ± .5	1.74 ± .21	.13
	12F	.56 ± .25	.25 ± .11	3.3 ± .5	1.45 ± .20	.17
	12-13F	.54 ± .26	.23 ± .10	3.7 ± .5	1.50 ± .20	.15
	9H	.35 ± .24	.13 ± .083	4.8 ± .5	1.77 ± .20	.073
June 8:	9I	.42 ± .24	.16 ± .085	8.0 ± .7	3.09 ± .27	.052
	11I	.41 ± .24	.16 ± .085	4.7 ± .5	1.77 ± .20	.090
	11I	.71 ± .27	.30 ± .12	3.8 ± .5	1.63 ± .22	.18
June 13:	11I	.79 ± .26	.26 ± .083	7.5 ± .6	2.47 ± .20	.10
	11I	.71 ± .29	.29 ± .12	5.5 ± .6	2.25 ± .25	.13
October:	11H	1.3 ± .29	.34 ± .077	6.0 ± .5	1.66 ± .16	.20
	11H	1.3 ± .30	.35 ± .083	9.4 ± .7	2.50 ± .19	.14
	11H	.43 ± .23	.15 ± .073	4.8 ± .5	1.66 ± .17	.090
	11H	.54 ± .24	.11 ± .046	6.1 ± .6	1.29 ± .12	.085
	11H	.52 ± .24	.17 ± .071	4.8 ± .6	1.53 ± .19	.11
	11H	.97 ± .29	.16 ± .048	8.7 ± .7	1.44 ± .11	.11
October 30:	11H	.75 ± .29	.21 ± .077	4.5 ± .5	1.27 ± .15	.17
	11H	.63 ± .28	.25 ± .10	7.3 ± .7	2.87 ± .26	.087
	11H	1.0 ± .30	.28 ± .083	8.1 ± .7	2.24 ± .19	.12
	12H	.55 ± .23	.19 ± .071	3.2 ± .4	1.11 ± .13	.17
	12H	.78 ± .29	.26 ± .095	4.2 ± .5	1.40 ± .17	.19
	12G	.59 ± .23	.20 ± .071	2.7 ± .4	.90 ± .13	.22
Average			0.22 ±0.027		1.83 ±0.24	0.12

[a] The locations are given in terms of the grid coordinates in figure 1.

Table 12. Plutonium concentrations in offsite soil, ANL, 1972

Location	Date collected	Plutonium-238		Plutonium-239		^{238}Pu/^{239}Pu
		(fCi/g)	(nCi/m^2)	(fCi/g)	(nCi/m^2)	
McKinley Woods State Park	June 27:	0.31 ±0.24	0.08 ±0.06	3.9 ±0.5	1.10 ±0.14	0.07
Pioneer Park, Naperville		.68 ± .27	.26 ± .10	4.0 ± .6	1.50 ± .21	.17
Saganashkee Slough		.59 ± .26	.20 ± .09	6.3 ± .6	2.09 ± .21	.09
McGinnis Slough	September 27:	.78 ± .46	.31 ± .19	4.8 ± .8	1.96 ± .31	.16
McCormick Woods		.43 ± .21	.15 ± .07	4.6 ± .5	1.55 ± .17	.09
Lake Delavan, Wisconsin	October 3	.48 ± .23	.14 ± .06	5.8 ± .5	1.58 ± .16	.08
Average			0.19 ±0.07		1.63 ±0.29	0.12

were collected near buildings in which plutonium had been used, so the possibility of plutonium in their vicinity exists. The levels of activity in these samples are not sufficiently above the fallout range to allow an unequivocal conclusion. Surveillance in these areas is continuing.

The samples collected downwind from Building 205 after the glove box explosion averaged 1.83 nCi/m^2 and ranged from 1.1 to 2.9 nCi/m^2. These values are also not sufficiently different from the offsite results to conclude with good probability that the samples contained plutonium from the explosion.

Composite monthly precipitation samples were analyzed for plutonium-239 by the same procedure as used on water samples. Concentrations, expressed in terms of ground deposition, ranged from 0.12 to 0.75 pCi/m^2 and averaged 0.4 pCi/m^2. The total 1972 deposition by precipitation was only 0.3 percent of the amount previously deposited, and implies that, in the absence of further testing, the soil content will not increase greatly.

The thorium and uranium content of the soil samples was also measured, the former by chemical separation and alpha spectrometry and the latter by a fluorophotometric method. The thorium-228 concentrations averaged 0.40 ± 0.04 pCi/g onsite and 0.43 ± 0.10 pCi/g offsite. The thorium-230 averaged 0.47 ± 0.04 pCi/g onsite and 0.45 ± 0.10 pCi/g offsite. The thorium-232 averaged 0.34 ± 0.03 pCi/g onsite and 0.37 ± 0.08 pCi/g offsite. No sig-

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nificant differences between on- and offsite concentrations were found. These are normal levels of the naturally-occurring thorium activities. Results of uranium analyses averaged 1.5 ± 0.2 pCi/g onsite and 1.3 ± 0.3 pCi/g offsite, and are quite similar to levels of uranium in soil found in previous years in this area (*7,8*). No evidence of uranium from Argonne was found. In terms of mass, the thorium concentrations were 3.1 μg/g onsite and 3.3 μg/g offsite and the uranium concentrations were 2.2 μg/g onsite and 1.9 μg/g offsite. Gamma-ray spectrometric analysis of these soil samples showed only traces of old fission products attributable to fallout, and no activity related to laboratory operations.

The results of plutonium-239 measurements in grass are given in table 13. The concentrations in terms of area were approximately the same on and off the site. Two onsite samples (June 7, 12L and 9I) are 1.5 to 2 times higher than the offsite samples, and these were collected near soil that also contained above average plutonium concentrations. However, it is not certain that any of the plutonium in these samples can be attributed to Argonne since grass collected in 1971 contained still higher concentrations both on and off the site (*9*) than were found this year. The differences observed are probably due to normal variations in fallout concentrations. In terms of deposition, the plutonium-239 concentration was a factor of 2000 to 5000 less than in soil from the same location. Uranium concentrations were similar to those reported last year (*10*).

Table 13. Plutonium-239 concentrations in grass, ANL, 1972

Location [a]	Date collected	Plutonium-239 concentration	
		(fCi/g)	(pCi/m²)
Onsite:			
12L	June 7:	2.3 ±0.7	0.46 ±0.14
12–13L		1.5 ± .4	.22 ± .07
9I	June 8:	4.2 ± .8	.67 ± .12
12I		1.6 ± .5	.35 ± .12
12H	October 17:	8.5 ±4.6	.33 ± .19
12H		4.5 ±3.7	.21 ± .18
12H	October 18:	4.4 ±1.7	.22 ± .08
12H	October 30:	2.3 ±1.6	.32 ± .21
Offsite:			
McKinley Woods State Park	June 27:	.87 ± .3	.17 ± .07
Lake Delavan, Wis	October 3:	2.8 ±1.9	.29 ± .19

[a] The onsite locations are given in terms of the grid coordinates in figure 1.

A study was made of the plutonium concentration in the Sawmill Creek bed below the laboratory wastewater outfall. The results are shown in table 14 along with the results from several control locations. Because the nature of the creek bottom prevented collection from a known area, results are expressed in terms of concentration rather than deposition. The lower concentrations (<10 fCi/g) were found in samples collected in areas where the flow rate is rapid and the bed was sandy and had little absorptive capacity. As the creek slows 90 meters below the outfall, the sedimentation increases, the bed becomes more silty and retentive, and higher plutonium concentrations occur. The highest creek results are similar to those of the slower moving Des Plaines River. Thorium and uranium concentrations in the creek bed followed the same pattern. Little, if any, plutonium released in the laboratory wastewater is retained by the creek bottom.

Table 14. Plutonium concentrations in benthic material, ANL, 1972

Location [a]	Concentration (fCi/g)		^{238}Pu/^{239}Pu
	Plutonium-238	Plutonium-239	
Des Plaines River, Willow Springs	1.7 ±0.3	21.8 ±1.1	0.078
Des Plaines River, Lemont	2.1 ± .4	33.3 ±1.3	.063
15K	1.1 ± .3	7.2 ± .6	.15
45 meters below 7M	1.1 ± .3	9.7 ± .8	.11
90 meters below 7M	1.3 ± .3	18.4 ±1.0	.071
140 meters below 7M	2.7 ± .4	25.9 ±1.3	.10
180 meters below 7M	2.2 ± .4	27.7 ±1.3	.079
230 meters below 7M	2.1 ± .4	32.0 ±1.4	.066
270 meters below 7M	2.0 ± .4	25.1 ±1.2	.080
370 meters below 7M	2.5 ± .4	24.0 ±1.2	.10
Mouth of Sawmill at Des Plaines	3.0 ± .4	34.2 ±1.4	.088

[a] Location 15K is above the ANL site. Location 7M is below the wastewater outfall. Both locations are in Sawmill Creek.

Radioactivity in milk

Raw milk was collected monthly from a local dairy farm and analyzed for several fission products. Barium-140, strontium-89, and iodine-131 were not present in concentrations greater than the minimum detectable amounts of 20 pCi/liter for iodine-131 and 2 pCi/liter for the other two nuclides. The cesium-137 and strontium-90 concentrations are given in table 15. These two nuclides are long-lived fission

Table 15. Cesium-137 and strontium-90 concentrations in milk, ANL, 1972

Date collected	Concentration (pCi/liter)	
	Cesium-137	Strontium-90
January 5	NS	4.0
February 2	<10	6.0
March 1	10	2.2
April 5	13	8.2
May 3	11	6.5
June 7	<10	6.9
July 5	<10	5.3
August 2	<10	4.8
September 6	<10	3.8
October 4	<10	3.9
November 1	<10	4.0
December 6	<10	4.7
Average	<11	5.0

NS, no sample.

products from past nuclear tests and their presence in milk is not related to Argonne operations. The average strontium-90 content decreased by 10 percent from last year, while the cesium-137 concentrations decreased about 30 percent.

The concentrations given in table 15 may be compared to the AEC standards for drinking water. These values are 300 pCi/liter for strontium-90 and 20 nCi/liter for cesium-137 if the daily intake of water is 2.2 liters. The consumption of 1 liter of milk per day would then result in an average intake of 0.75 percent of the strontium-90 and <0.025 percent of the cesium-137 AEC standards. Using the standards specified by the Federal Radiation Council, 1 liter of milk is equivalent to <0.3 and 2.5 percent of the daily intake guides for cesium-137 and strontium-90, respectively.

Penetrating radiation

Measurements of gamma-ray dose were made with thermoluminescent dosimeters (extruded calcium fluoride chips, dysprosium-activated) calibrated with an NBS standard radium-226 source. Each measurement was the average of 3 to 6 chips exposed in the same package. Exposure times ranged from 44 to 74 days (except for one 133-day exposure). Individual results were calculated in terms of annual dose rate, and these were weighted according to their exposure times in calculating the average for a location.

The measurements were made throughout the year at a number of locations at the site security fence to determine the dose that might be due to Argonne operations at the closest uncontrolled approach to the laboratory. The actual site boundary varies from 140 to 1400 meters from the security fence, and over most of the perimeter is at least 450 to 900 meters from the fence. The closest public access to potential radiation sources is at coordinate 8H. At this location, the public is allowed to visit a preexisting cemetery (St. Patrick's Cemetery). Measurements were also made at several locations on the site within the fence, and at several offsite locations for comparison purposes. The results are given in tables 16, 17, and 18 for the offsite, ANL site security fence, and onsite locations, respectively.

The offsite measurements were quite uniform both by location and by period. Ninety-five percent of the results were in the range from 94 to 114 mrem/year. Only one anomalous result was obtained, 121 mrem/year for the second measurement at Lombard; all other results fell within 2 standard deviations (95-percent confidence limits) of the average for a single result, 105 ± 11 mrem.

Table 16. Environmental penetrating radiation at offsite locations, ANL, 1972

Location	Period of measurement	Days	Dose rate (mrem/yr)
Downers Grove	2/17- 4/29 (2)	72	106
	5/12- 6/29 (2)	48	96
	6/29- 9/11	74	103
	7/ 6- 9/11 (6)	67	111 ± 9
	9/11-11/21	71	112
	11/21- 1/ 5	45	105
Average			106 ±11
Woodridge	2/17- 5/ 1	74	109
	9/ 8-11/21	74	105
	11/21- 1/ 4	44	103
Average			106 ± 3
Lemont	2/17- 5/ 1	74	103
	6/29- 9/ 7	70	105
	9/11-11/21	71	101
Average			103 ± 8
Lombard	6/29- 9/ 8	71	107
	11/21- 1/ 5	45	121
Average			112
Naperville	6/29- 9/ 8	71	94
Hinsdale	7/ 5- 9/ 8	65	114
Plainfield	11/21- 1/ 4	44	103
Oak Lawn	9/ 8-11/21	74	98
	11/21- 1/ 4	44	102
Average			99
Overall average			105 ± 5

Table 17. Environmental penetrating radiation at ANL site security fence, 1972

Location	Period of measurement	Days	Dose rate (mrem/yr)
13D:	2/17– 4/29	72	76
	7/ 5– 9/11	68	85
Average			81
14I:	2/17– 4/29	72	109
	9/ 8–11/21	74	111
	11/21– 1/ 4	44	122
Average			113 ± 14
18J	6/29– 9/ 8	71	100
14L:	2/17– 5/ 1	74	104
	7/ 5– 9/ 8	65	101
	9/ 8–11/21	74	100
Average			102 ± 4
12–O:	2/17– 4/29	72	108
	5/12– 6/29	48	98
	6/29– 9/ 8	71	108
Average			105 ± 11
12N:	6/29– 9/ 8	71	98
	9/ 8–11/21	74	107
Average			103
10M	11/21– 1/ 4	44	111
10L	2/17– 4/29	72	111
7I:	6/29– 9/11	74	350
	9/11–11/21	71	509
Average			428
8G:	2/17– 4/29	72	131
	5/12– 6/29	48	111
	6/29– 9/11	74	128
	9/11–11/21	71	134
	11/21– 1/ 4	44	139
Average			128 ± 21
8F:	2/17– 4/29	72	121
	5/12– 6/29	48	108
	6/29– 9/ 8	71	110
	9/ 8–11/21	74	116
	11/21– 1/ 4	44	111
Average			114 ± 10
9EF:	2/17– 4/29	72	114
	5/12– 6/29	48	112
	6/29– 9/ 8	71	112
Average			113 ± 2
10E:	2/17– 6/29	133	98
	9/ 8–11/21	74	111
Average			103

If it is assumed that the offsite readings accurately represent the average natural radiation background of the area, a result between 94 and 116 mrem/year may be considered normal with a 95 percent probability. Only 2.5 percent of the measurements of a natural background radiation field should be higher than 116 mrem/year and 2.5 percent lower than 94 mrem/year. The offsite average, 105 mrem/year, is almost identical with that obtained in 1971, 104 mrem/year.

Examination of the site security fence measurements (table 17 and figure 3) show that only three locations gave average readings outside the normal range and two locations occasionally gave readings outside the normal range. The latter finding can simply be part of the normal spread indicated above. The dose rate at location 13D was well below the normal range, as it was in 1971, probably because of the large amount of subsurface gravel in the area containing below average concentrations of natural activities. Two locations were above normal, 8G and 7I, both on the south security fence. The abnormal dose rate at 7I, approximately 300 mrem/year, was due to radioactive materials in a radioactive waste storage area several hundred meters north of the fence.

Table 18. Environmental penetrating radiation on the ANL site, 1972

Location	Period of measurement	Days	Dose rate (mrem/yr)
9H—75 m east of CP-5	2/17– 4/29	72	1 900
	6/29– 9/ 8	71	1 200
	9/ 8–11/21	74	435
	11/21– 1/ 4	44	1 640
Average			1 250
9G—75 m west of CP-5	6/29– 9/ 8	71	346
	9/ 8–11/21	74	452
8H—Heliport	2/17– 4/29	72	149
	7/ 5– 9/11	68	133
7I—North fence of waste storage area	2/17– 4/29	72	1 270
	5/12– 6/29	48	1 170
	6/29– 9/ 8	71	864
	11/21– 1/ 4	44	2 360
Average			1 330
7I—Waste storage area	5/12– 6/29	48	860
	11/21– 1/ 4	44	2 360
7I—West fence of waste storage area	9/11–11/21	71	496
Average			1 105
10I—Bluff Road, NW of ZGS	5/12– 6/29	48	106
	6/29– 9/ 8	71	108
9H—North of building 315, 225 m south of CP-5	6/29– 9/ 8	71	248
	11/21– 1/ 4	44	290
7-8J—NW of storage area	5/12– 6/29	48	125
	6/29– 9/11	74	135
11H—South of 205, 500 m north of CP-5	5/12– 6/29	48	102
	6/29– 9/ 8	71	115
9J—ZGS area, south	7/ 5– 9/11	68	109
	9/ 8–11/21	74	113
	9/11–11/21	71	120
Average			114
9K—ZGS area, east of Meson building	9/ 8–11/21	74	131
	11/21– 1/ 4	44	188
13I—Building 202 parking lot	2/17– 4/29	72	78
14I—Building 202, south	6/29– 9/ 8	71	118
13I—Building 202, north	6/29– 9/ 8	71	89
Average			95
13H—Building 203, north	9/ 8–11/21	74	122
	11/21– 1/ 4	44	119
13G—Building 206, west	9/ 8–11/21	74	97

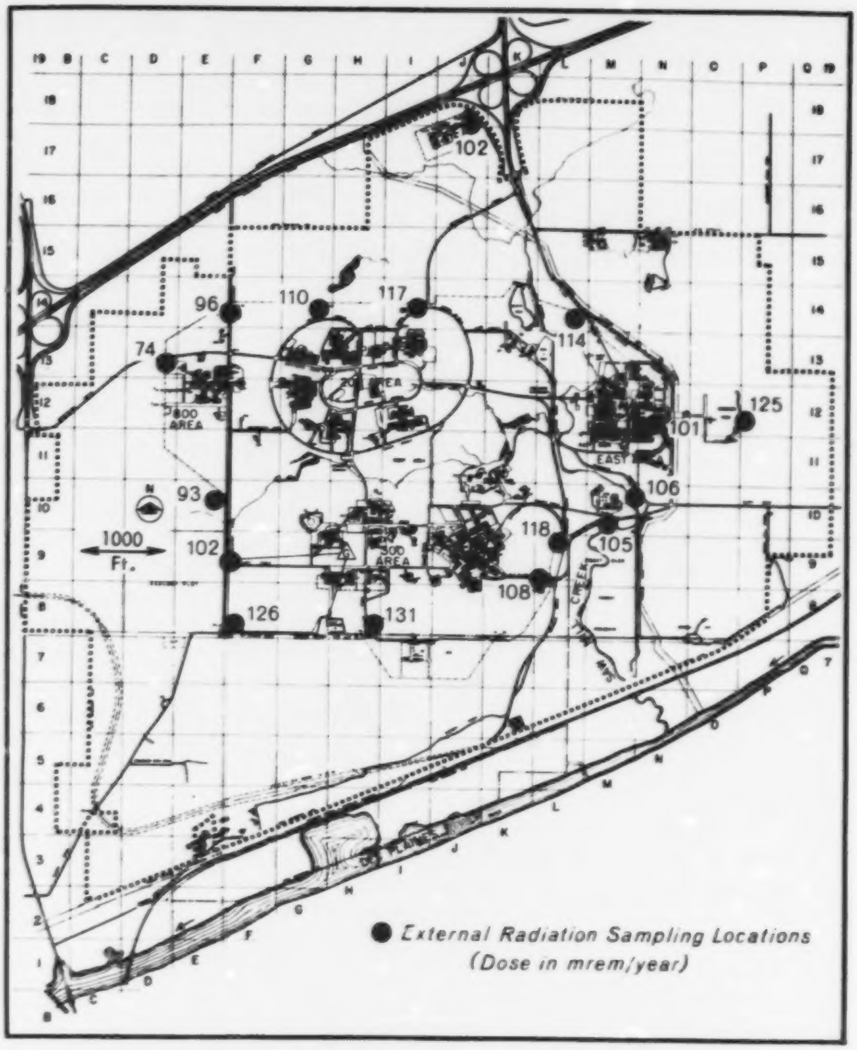
102
96
110
117
74
114
200 AREA
800 AREA
125
101
EAST
93
106
1000 Ft.
102
300 AREA
118
105
108
126
131
DES PLAINES
CREEK
● External Radiation Sampling Locations
(Dose in mrem/year)

Figure 3. External radiation measurements, Argonne National Laboratory

Radioactive waste is stored and packaged in this area for shipment to waste burial sites elsewhere. Readings in the center of the storage area (table 18) were as high as 2.3 rem/year. The area between the site security fence and the site boundary in this vicinity is rugged and heavily wooded, and the land rises steeply from the Des Plaines River. As a result, the area is relatively inaccessible and no individuals frequent this location. Based on measurements made north and west of the storage area, the dose rate at the south boundary line, about 590 meters from the fence, would be indistinguishable from background levels. The waste storage area may be considered as a stationary gamma-ray source in considering the variation of dose with distance. The strength of the source varies, however, as material is moved in and out of the area.

The dose rate at 8G, 128 mrem/year, is about

20 mrem/year above the normal average. At this location, there are three possible sources for above-normal readings; direct radiation from the waste storage area, direct radiation from the low power (10 W to 10 kW) reactors and from a tandem Van de Graaff generator in Building 315 (location 9H) and argon-41 from the CP-5 reactor at location 9H. The abnormal reading at 9H, north of Building 315 (264 mrem/year) (onsite) makes this building a possible, but minor, contributor to the dose at 8H. The contribution of CP-5 is considered negligible since onsite readings at 11H (as far north of CP-5 as the 8H location is south) and at location 10I (west of CP-5 and slightly farther from CP-5 than 8H) were all normal. The wind roses from this area show a maximum from the west and southwest, so that higher doses from CP-5 should be observed to the north and east of the reactor. Elevated readings were obtained onsite at location 8H (141 mrem/year), between the waste storage area and the 8G location and at location 7/8J, but to the east. These readings are consistent with the interpretation that the elevated 8G reading is due primarily to the radioactive materials in the waste storage area. Although additional measurements in the area are indicated to determine the contribution of the various sources to the dose at 8G unequivocally, the waste storage area is believed to be the major contributor.

The applicable radiation protection standards for whole body external radiation dose to the general population is a maximum of 500 mrem/year to critical individuals, or, if individual doses are not known, 170 mrem/year to a suitable sample of the exposed population. The latter criterion assumes that the maximum dose to individuals in the sample will not exceed the average by more than a factor of 3 (*11*). The dose from Argonne operations at location 8G (about 20 mrem/year) is well within these limits, particularly since the individuals visiting the cemetery are exposed for only a very small fraction of the year. The dose at the fence line south of the waste storage area, about 300 mrem/year, is 60 percent of the 500 mrem/year limit to individuals, although it is about twice the 170 mrem limit to the "suitable sample." However, as noted previously, there are no individuals being exposed at that location, and the dose at the south boundary of the site is normal. It is also appropriate here to consider the "as low as practicable" guideline limits being proposed for light-water cooled power reactors (*12*). Various limits are being considered, and at present, 10 mrem/year is the one most likely to emerge. The annual dose at 8G exceeds this value, but as pointed out earlier, individuals receive exposures only when visiting the cemetery. There are no full-time residents living close enough to the site boundary to receive 10 mrem/year.

Other above-normal readings of interest on the site (table 18) are those 70 meters east (1.3 mrem/year) and west (400 mrem/year) of CP-5; just north of building 315 at location 9H (264 mrem/year), and at 9K, just east of the ZGS Meson building (152 mrem/year). The maximum occupational dose at these locations is about 20–25 percent of the anual dose considering the amount of time employees spend on the site. The applicable annual standard for occupational exposure is considerably higher, 5 rem.

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Previous coverage in *Radiation Data and Reports:*

Period	Issue
January–December 1971	May 1973

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2. Bettis Atomic Power Laboratory [4]
January–December 1972

Westinghouse Electric Corporation
Pittsburgh, Pa.

The Bettis Atomic Power Laboratory is operated by the Westinghouse Electric Corporation for the U.S. Atomic Energy Commission (AEC) and is engaged in the design and development of nuclear power reactors.

The laboratory is situated on a 200 acre tract of land in the Borough of West Mifflin, Pa., approximately 7 miles southeast of the city of Pittsburgh. A map of the Bettis Laboratory and surrounding area is provided in figure 4.

This document summarizes the results of the effluent and environmental monitoring program conducted at the laboratory for January–December 1972. The program has been continuously maintained since 1959 and regulates the disposal of solid, liquid and airborne effluents from the laboratory. Since its inception, the data obtained from this program have shown that the laboratory's procedures for controlling effluents are adequate to ensure that all releases to the environment are made in accordance with the applicable requirements. The program includes sampling and analysis of exhaust air, liquid effluents, and silt and water samples from the small streams on the laboratory site and in the nearby area. Evaluation of these data, along with the analysis of the environmental radiation measurements, provides the basis for assessing the environmental impact due to laboratory operations.

Monitoring of liquid effluent

The Bettis Atomic Power Laboratory consists of a main laboratory area and a critical facilities area. Liquid effluent from these areas consists of uncontaminated coolant and process water (e.g., air conditioning coolant), surface runoff rainwater, and controlled liquid releases whose measured radioactivity concentrations are less than the applicable discharge limit of 300 pCi/liter. The liquid discharge limit applicable to laboratory releases is conservatively based on the maximum permissible concentration of strontium-90 in water.

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[4] Summarized from Environmental Monitoring at Major U.S. Atomic Energy Commission Contractor Sites, WASH-1259 "Bettis Atomic Power Laboratory for 1972".

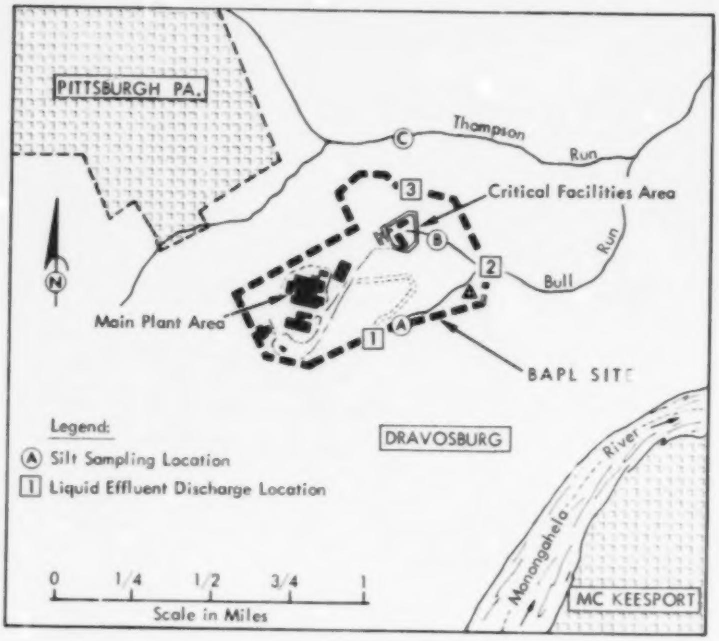
PITTSBURGH PA.
C
Thompson
Run
3
Critical Facilities Area
B
2
Bull
Run
N
Main Plant Area
1
A
BAPL SITE
Legend:
A Silt Sampling Location
1 Liquid Effluent Discharge Location
DRAVOSBURG
River
Monongahela
MC KEESPORT
0
1/4
1/2
3/4
1
Scale in Miles

Figure 4. Bettis Atomic Power Laboratory sampling stations

Effluent sampling

Process liquids resulting from laboratory operations in which radioactive materials are handled are collected in holding tanks. Water is released to the environment only when the measured activity is less than the AEC standards. Liquid effluents having a concentration of radioactivity in excess of the AEC standards are treated either by evaporation or ion exchange and filtration. Water from the holding tanks is sampled and analyzed for gross alpha and gross beta-gamma activity to determine if further treatment is needed or if the water has a low enough concentration of radioactivity to release. The residue from the liquids which are evaporated is solidified and shipped offsite for burial as solid waste.

Samples of laboratory liquid effluents were collected and analyzed to ensure that all applicable water quality standards were met.

Analytical techniques

Samples are prepared for analysis by evaporating 100 ml aliquots of process liquid to deposit suspended and dissolved solids on 5-cm aluminum planchets. Alpha and beta-gamma measurements are obtained on an automatic sample counter.

The automatic sample counter uses a gas flow, 2π proportional counter with a surrounding NaI(Tl) crystal in anticoincidence to reduce the background radiation detected by the proportional counter. The combination of the guarded sample detector and extensive lead shielding permits the unit to maintain low background count levels. Calibrations for the counter are performed using plutonium-239 (alpha) and cesium-137 (beta-gamma) standard sources. The minimum detectable levels for alpha and beta-gamma radioactivity are 5.0 pCi/liter and 10 pCi/liter, respectively.

All analyses for water quality parameters were performed by a subcontractor utilizing standard laboratory techniques described in reference (*13*).

Effluent monitoring results

The net radioactivity released from the laboratory during January–December 1972 amounted to a quantity that was not significantly different from the waste discharge permit quantity of 0.0011 curie. During this period, the total liquid effluent volume from the Bettis site, including surface runoff rainwater and process waters, was 220.5×10^6 gallons. Hence, the net average radioactivity concentration of the liquid effluent released to the environment was 1.31 pCi/liter or 0.44 percent of the AEC standard. The radioactive constituents contained in the liquid effluent which are attributable to laboratory operations are strontium-90, cesium-137, and cesium-134.

Monitoring of airborne effluent

All of the laboratory stacks which exhaust air from areas where radioactive materials are handled are monitored on a continuous basis. A daily sample of stack effluent particulate matter is collected for analysis on filter paper at a sampling flow rate of 20 liters per minute. At two locations where the potential for iodine-131 releases can exist, sampling of iodine-131 concentrations is also performed by utilizing charcoal-impregnated cellulose filters.

Until April 1972, the filters were counted for alpha and beta-gamma radioactivity using alpha scintillation and end-window Geiger-Mueller detectors, respectively. The minimum detectable levels for particulate alpha and beta-gamma radioactivity were 0.1 pCi/m^3 and 1.0 pCi/m^3, respectively. The alpha detector was calibrated with a thorium-230 standard source, and this Geiger-Mueller counter was standardized using cesium-137. Since April 1972, the filters have been counted on an automatic sample counter. This system has been calibrated for counting the alpha and beta-gamma activity deposited on filters using a thorium-230 standard source for alpha activity and cesium-137 for beta-gamma activity. The minimum detectable activities with the improved detector have decreased to 1.5 fCi/m^3 alpha and 11.0 fCi/m^3 beta-gamma.

The iodine-131 is counted with an end-window Geiger-Mueller counter. The minimum detectable activity for iodine-131 is 500 pCi/m^3. Calibration is performed with a cesium-137 standard.

Although the techniques used to measure the concentration of particulate radioactivity in air are sensitive to levels well below natural background, the radioactivity levels in most of the air exhausted from the laboratory were less than the minimum detectable level. In such cases, conservative calculations which assume that the air discharged contained particulate radioactivity at the minimum detectable level were used. The results indicate that less than 0.024 curie was released to the atmosphere in 1972. On this basis, the average concentration of airborne particulates in the air released was less than 5.7 percent of the AEC radiation standards for an unknown mixture of radionuclides in air. The general public outside the boundary of the laboratory was not exposed to radiation levels in excess of natural background, and the quantity of airborne radioactivity released was too small to have had any significant effect on the quality of the human environment.

Surface water monitoring

The principal purpose of the surface water sampling program is to provide additional assurance that the laboratory procedures for the control of radioactivity are adequate. The net amount of radioactivity measured in the laboratory effluents is compared with the net difference between the natural radioactivity in the city drinking water and precipitation and the radioactivity in surface water leaving the site. Samples of the water are analyzed for gross alpha and gross beta-gamma radioactivity.

The Bull Run sampling station collects approximately 50 ml aliquots of effluent water from a basin which is automatically siphoned and refilled at a rate proportional to the effluent flow. The number of aliquots is counted by a

Table 19. Summary of the surface water monitoring program, BAPL, 1972

Parameter	Number of samples	Concentration (pCi/liter)			Volume (gallon × 10^6)	Total activity (Ci)
		Maximum	Minimum	Average [a]		
Effluent	62	17.9	2.3	14.2 ± 1.4	[b] 220.5	0.0118 ± 0.0012
Influent	12	10.0	3.3	5.9 ± 1.2		.0049 ± .0010
Precipitation runoff	12	91.9	6.8	28.6 ± 7.1	[c] 47.26	.0051 ± .0013
Residual (effluent less influent and precipitation)						.0018 ± .0020

[a] At 95-percent confidence level.
[b] Measured at the Bull Run sample station.
[c] Assumes that precipitation runoff from 80 percent of roofs and paved grounds enters the laboratory storm sewer network.

mechanical register which permits calculation of the total effluent volume.

The analytical techniques employed are the same as those used for effluent monitoring and the minimum detectable levels for the gross alpha and gross beta-gamma analyses are 5.0 pCi/liter and 10 pCi/liter, respectively.

The results of the surface water monitoring program are summarized in table 19. As noted in table 19, a release of 0.0018 ± 0.0020 curie due to laboratory operations is derived by subtracting the radioactivity measured in the effluent water supply and in the precipitation and surface runoff from the effluent radioactivity measurements. Comparison of this calculated radioactivity release with the activity computed by summing all releases authorized by the discharge permit (0.0011 curie) indicates that within the uncertainties of the measurement, there is no significant difference between the two values. These data confirm that the procedures used by the laboratory to control radioactivity are effective in protecting the environment.

Dosimetry monitoring

Environmental radiation levels are monitored by 50 lithium fluoride thermoluminescent devices. Thirty-four of these devices are posted on the laboratory security fence at approximately 100-foot intervals. The remaining 16 are located at points on or near the laboratory

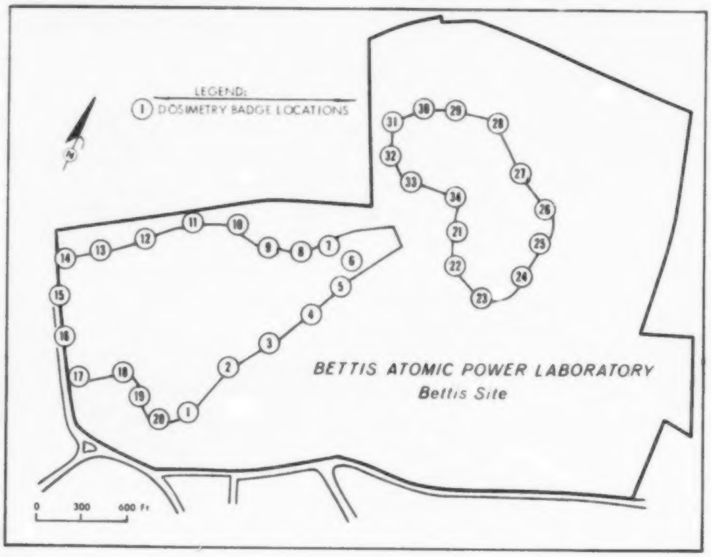

Figure 5. Dosimetry badge locations, BAPL

site boundary. The locations of the thermoluminescent monitors are shown in figure 5. In addition, nine control thermoluminescent dosimeter monitors are placed at locations remote from the laboratory site in order to provide independent measurements of local natural background radiation levels.

The onsite thermoluminescent monitors and the nine control monitors are processed quarterly. Calibration of the system is accomplished by readout of dosimeters exposed to a cesium-137 standard source.

A summary of quarterly environmental radiation dosimetry data, along with control dosimetry results, is given in table 20. It is concluded from this comparison that the radiation exposure to the general public at the site boundary was not above that received from natural background radiation.

Table 20. Environmental radiation measurements, BAPL, 1972

	Dose rate (mrem/calendar quarter)		
	Maximum	Minimum	Average [a]
Control	33.3	13.4	25.9
Site boundary	37.5	19.5	25.4

[a] Average values have a 30 percent deviation from the mean at the 95-percent confidence level.

Stream silt sampling

Silt samples are routinely collected from the three small streams on the laboratory site and from a remotely located control stream. A more extensive, improved, silt sampling liquid effluent and environmental monitoring program was implemented at the laboratory on October 1, 1972. The expanded sampling program increases the number of samples taken from Bull Run since it is the largest of the three streams on the site. It includes the collection and analysis of silt samples from several onsite and offsite locations. The revised sampling program is designed to provide increased confidence that laboratory operations have an insignificant effect on the environment.

In the new program, a total of 114 silt samples are collected annually from the control stream and the three streams which carry laboratory liquid effluents. The majority of these samples, 24 per quarter from 6 different sampling locations, are collected from Bull Run. Three samples are collected from each of the other three streams, semiannually. A total of 38 silt samples were collected annually from all locations prior to the implementation of the revised silt sampling program.

All of the silt samples collected are analyzed for gross alpha, gross beta-gamma and cesium-137 radioactivity.

The silt samples are oven dried, milled, homogenized and evenly distributed on a planchet. The gross radioactivity measurements are obtained by counting a 400 milligram sample for 100 minutes on a low background proportional automatic sample counter. Minimum detectable levels for these parameters are 4.0 pCi/g alpha and 1.4 pCi/g beta-gamma, although these values can vary to some degree due to self-absorption correction factors which are dependent on the exact sample weight. Self-absorption correction factors have been measured and are used when needed. Calibrations for this measurement are performed with uranium-235 (alpha) and cesium-137 (beta-gamma) standard sources.

Measurements of cesium-137 silt activity are obtained with a 3-inch diameter by 3-inch high NaI(Tl) scintillation detector. The average size of the silt samples for these measurements is 175 g. The system is calibrated with a set of dirt samples to which known amounts of a standard cesium-137 solution have been added. The cesium-137 concentration is calculated by integration of the 0.66 MeV photopeak area following subtraction of the Compton background continuum from higher energy gamma-rays. The minimum detectable activity for cesium-137 in silt varies from 0.45 pCi/g for a 100 g sample to 0.25 pCi/g for a 200 g sample.

Average radioactivity concentrations at the 95 percent confidence level of 8.3 ± 6.4 pCi/g alpha and 25.3 ± 2.8 pCi/g beta-gamma were measured in the control stream silt samples. The radioactivity measurements in the two streams which carry Critical Facility Area liquid effluents are not statistically different from the control stream values and are of no environmental significance.

Average net radioactivity concentration at the 95 percent confidence level of 4.6 ± 3.7 pCi/g alpha and 36.8 ± 15.7 pCi/g beta-gamma were measured over the initial 1.9 miles of Bull Run. The maximum and minimum net concentrations measured in Bull Run ranged from less than the minimum detectable level (4.0 pCi/g) to 10.5 pCi/g alpha, and from less than the minimum detectable level (1.4 pCi/g) to 66.4 pCi/g beta-gamma. The majority of this radioactivity is due to cesium-137, for which an average concentration of 33.2 ± 14.3 pCi/g was measured. The range on the cesium-137 concentrations measured in Bull Run silt was from 2.65 pCi/g to 54.10 pCi/g.

An analysis was performed for that portion of the stream in which levels of radioactivity above background were measured to determine the quantity of radioactivity present and its effect on the environment. For the purpose of the analysis, the average concentration of 36.8 ± 15.7 pCi/g beta-gamma radioactivity was conservatively assumed to be uniformly deposited over the topmost 2 inches of stream silt. Using this assumption, this analysis indicates that after 23 years of laboratory operations, the total accumulated activity in silt is less than 0.01 curie. Even though the stream silt is not used as a source of food, a member of the general public could continuously consume food at approximately the levels of cesium-137 found in the silt without exceeding the internal exposure limits recommended by the National Council on Radiation Protection and Measurement.

Laboratory net releases have significantly decreased over the last 5-year period, and the surface water monitoring program confirms that these releases are strictly controlled. It is therefore concluded that the radioactivity in Bull Run silt has an insignificant effect on the environment. Further, there is no evidence of a significant buildup of radioactivity in Bull Run and only background activity is present 1.9 miles from the juncture with the Monongahela River.

Estimates of radiation dose to man

Although the amounts of radioactivity released from the laboratory are small and the results of environmental monitoring show that laboratory operations have had no significant effect on the environment, conservative estimates of the radiation dose to man have been made by analyzing the pathways whereby radioactivity might be transferred from the environment to man. These analyses considered direct exposure, such as by drinking the water in Bull Run and indirect pathways, such as consumption of food. The assumed pathways used in these analyses are hypothetical since the public is not dependent on Bull Run and the laboratory storm drains for food and water. These analyses showed that exposures to man from this radioactivity would be too low to measure and could only be estimated through conservative calculations. Based on the radioactivity released during 1972, the maximum radiation exposure to any member of the general public would be less than 2.6 millirem. This is a small fraction of average annual exposure of 125 millirem to members of the general public from natural radioactivity. The maximum radiation exposure to any member of the general public and the exposure to the population within a 50-mile radius of Bettis are significantly less than 1 percent of the AEC standard. Thus, radioactivity released from Bettis has not caused significant radiation exposure to the general public.

Summary

All potentially radioactive liquid and airborne effluents are filtered and treated prior to release to ensure that all such releases are as low as practicable. The amount of radioactivity released during calendar year 1972 was small and significantly below the AEC standards specified in the applicable regulations.

The quantity of radioactivity released in water during 1972 amounted to a quantity that was not significantly different from the water discharge permit quantity of 0.0011 curie. Since strontium-90 is the predominant and longest-lived radionuclide in the laboratory effluents, the laboratory radioactivity concentration guide is conservatively based on the AEC standard for strontium-90 in water. The average concentration of radioactivity in liquid effluents was only 0.44 percent of the AEC

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standards; all liquids were released at concentrations far below the AEC standards. Airborne particulates released to the atmosphere contained less than 0.024 curie and were generally below the sensitivity of the measuring equipment. The airborne particulate radioactivity concentration is less than 5.7 percent of the applicable AEC standard for an unknown mixture of radionuclides in air. Solid radioactive waste materials are shipped in Department of Transportation-approved, sealed containers to an Atomic Energy Commission-approved burial ground. Hence, these waste products have no effect on the quality of the human environment in the communities surrounding the laboratory. All other waste disposal processes are designed to ensure that all such releases from the laboratory are made in accordance with the applicable regulations.

Water quality measurements are made on water samples, which are collected from the small streams on the laboratory site. In addition, analysis of the radioactivity in silt from these streams is also performed. The environmental radiation levels within and at the laboratory boundary are measured by means of thermoluminescent dosimetry monitoring devices. Analyses of these environmental monitoring data indicate that the operation of the laboratory during 1972 did not have any significant effect on the quality of the human environment at the laboratory or surrounding communities.

REFERENCE

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Recent coverage in *Radiation Data and Reports:*

Period	Issue
January–December 1971	March 1973

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3. Paducah Plant [5]
January–December 1972

Union Carbide Corporation
Paducah, Ky.

The Paducah Gaseous Diffusion Plant (PGDP) is located in McCracken County, Kentucky, about 4 miles south of the Ohio River and 20 miles east of the confluence of the Ohio and Mississippi Rivers. The plant is an AEC-owned, contractor-operated uranium enrichment cascade with associated uranium hexafluoride (UF_6) manufacturing plant and extensive support facilities. The Paducah processing facility now consists of 1812 diffusion stages housed in five buildings with a total ground coverage of about 74 acres. Including support facilities, the plant has a total complement of about 30 permanent buildings.

Except for the large raw water treatment plant, all buildings are within a 750-acre fenced area. A buffer area of at least 1200 feet in depth exists on all sides of the fenced area. Beyond the AEC-owned buffer is an extensive wildlife management area leased or deeded to the Commonwealth of Kentucky. There is no habitation within 3,000 feet of any of the process buildings. The nearest incorporated towns are Metropolis, Ill., located 5 miles to the northeast and LaCenter, Ky., located 11 miles southwest. Paducah, Ky., a city of 35 000, is located 12 miles east of the plant.

The primary plant, the diffusion cascade, contains a physical process in which UF_6 is fed into the system, pumped through the diffusion stages and eventually is removed, still as UF_6. The product is enriched in the fissionable uranium-235 isotope and the "tails" are withdrawn at the bottom as depleted UF_6. The process pumps require electric power, lubrication, and air for cooling. The compressed bases are cooled by a heat exchange fluid, which is in turn cooled by recirculating cooling water.

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[5] Summarized from "Environmental Monitoring at Major U.S. Atomic Energy Commission Sites, Paducah Plant, Calendar Year 1972" WASH-1259.

The basic inputs to the feed manufacturing plant are hydrogen, anhydrous hydrogen fluoride (HF), and uranium oxide (UO_3). The product is uranium hexafluoride (UF_6). Theoretically, 1000 tons of HF are required to convert 2000 tons of uranium from the oxide to UF_6.

Some of the depleted UF_6 from the cascade is reacted with hydrogen to recover HF and to convert the volatile UF_6 to the more easily stored UF_4. In the same facility, the Metals Plant, some of the UF_4 is reduced to metal by reaction with magnesium. The reaction results in the largest volume solid waste product of the plant processes, a magnesium fluoride slag.

Air monitoring

Continuously operating air sampling stations are established on electric power poles at four locations on the perimeter fence and at five locations approximately 1 mile from the plant site. Each sampling station consists of a metal housing sheltering a 2-inch membrane filter holder and containing (as the air flows) a flow meter, a gas scrubber, flow throttling valve, and an air pump. Air flow through the system is adjusted to 0.3 cfm (86 cubic meters per week). The membrane filter is removed each week for long-lived alpha and beta radioactivity determinations.

The gas bubbler is filled to about a 7-inch depth with glass beads to disperse the air in the scrubbing solution of about 1 liter of 0.025 normal sodium hydroxide. This collection technique is essentially 100 percent efficient for HF collection in the parts per billion range. The fluoride content is determined by the specific ion electrode method. Results of the environmental air sampling program are shown in table 21.

Alpha radioactivity attributed to uranium from the plant averaged less than the minimum detectable level at the outer edge of the buffer zone. The samplers on the north and east perimeter fences, which are nearest the Feed Plant and the Metals Plant, collected detectable amounts. Beta radioactivity levels at all stations and in all samples were far below the applicable concentration guide.

All gas scrubber samples collected offsite over weeklong periods and analyzed for fluorides were within the Kentucky ambient air stand-

Table 21. Environmental air sampling results, Paducah Plant, January-December 1972

Sample point [a]	Number of samples	Alpha radioactivity concentration (fCi/m³)			Percent of AEC standard	Beta radioactivity concentration (pCi/m³)			Percent of AEC standard
		Maximum	Minimum	Average [b]		Maximum	Minimum	Average [b]	
At plant perimeter fence:									
North	52	480	<20	<30±20	(c)	11	<0.1	<2.4±0.63	(c)
East	52	540	<20	<30±21	(c)	3.9	<.1	<.8± .22	(c)
South	52	20	<20	<20±10	(c)	1.2	<.1	<.3± .07	(c)
West	52	30	<20	<20±20	(c)	1.9	<.1	<.5± .14	(c)
1 mile outside plant perimeter fence:									
North	52	30	<20	<20±10	[d] <1	1.1	<.1	<0.3± .03	[e] <0.03
East	52	20	<20	<20±10	<1	.5	<.1	<.2± .06	<.02
Southeast	52	40	<20	<20±10	<1	.5	<.1	<.2± .03	<.02
South	52	20	<20	<20±10	<1	.6	<.1	<.2± .03	<.02
West	52	30	<20	<20±10	<1	.4	<.1	<.2± .03	<.02

[a] See figure 6.

[b] The plus-or-minus (±) values represent the 95-percent confidence limits. The 95-percent confidence limit is calculated from the standard deviation of the average, assuming a normal frequency distribution, and is a measure of the variability in the range of concentrations measured. It does not represent the conventional error in the average of repeated measurements on identical samples. Data which are below the minimum detectable limit are expressed as less than (<) the minimum detectable value. In computing average values, sample results below the detection limit are assigned the detection limit value with the resulting average value being expressed as less than (<) the computed average value.

[c] Environmental standards not applicable.

[d] The AEC standard for natural uranium is 2 pCi/m³.

[e] The AEC standard for thorium-234 is 1 000 pCi/m³.

Table 22. Uranium concentrations in environmental water samples, Paducah Plant, January-December 1972

Sample point [a]	Number of samples	Uranium (mg/liter)				
		Maximum	Minimum	Average	Standard	Percent of standard
Ohio River:						
9	11	0.008	0.001	0.003 ± 0.0014	[b] 0.009	33
50, 51, 52, 53 composite	11	.011	.001	.002 ± .0018	[b] .009	22
Big Bayou:[c]						
1	12	.008	.001	.002 ± .0012	[d] 60	0.003
3	52	.052	.001	.015 ± .0033	[d] 60	.03
Mouth of creek:						
21	11	.110	.001	.021 ± .033	[e] 60	.04
Little Bayou:[f]						
17	52	2.22	.019	.441 ± .130	[d] 60	.7
Ground water:[c]						
11	12	.004	.001	.001 ± .0006	[d] 60	.002
12	12	.007	.001	.002 ± .0012	[d] 60	.003

[a] See figure 6.
[b] Kentucky Water Pollution Control Commission regulation WP-4-1 (14).
[c] Unclassified.
[d] AEC concentration guide equivalent for natural uranium.
[e] Ohio River Valley Sanitation Commission Pollution Control Standard 70-1 (standard for thorium-234) (15).
[f] Unclassified stream on government property.

ard. The average results were about 20 percent of the standard.

Water monitoring

Water samples are collected continuously in the Big Bayou and in the Little Bayou (essentially a drainage ditch traversing AEC and TVA property). Grab samples are taken each month from several locations in the Ohio River, at the mouth of the Bayous, and from two test wells. The effluent from the sewage disposal plant is sampled for weekly determinations of suspended solids.

The extensive water sampling and analyses showed no increase in concentrations of the parameters of interest in either the Ohio River or in ground water (tables 22–23). The concentrations of uranium and beta radioactivity in the Big Bayou and at the mouth of the creek were well within the Ohio River Valley Water Sanitation Commission and AEC limits.

Soil monitoring

Soil samples were collected from near the north, east, south, and west AEC property boundaries. Plugs of soil 3½ inches in diameter were removed from the ground down to a uniform depth of 4 inches, dried, pulverized, and blended before analysis. Duplicate aliquots were spiked with uranium-233 and the uranium was quantitatively removed and analyzed by mass spectrometry. The results (table 24) ranged from 1.1 ppm to 2.0 ppm. Background in this area was determined in prior years to be 0.9 ppm. None of these concentrations would be expected to have a significant impact on the environment.

Table 24. Concentrations of uranium in soil, Paducah Plant, January-December 1972

Sample point	Concentration (μg/g)
At AEC property boundary:	
North	2.0
East	1.1
South	2.0
West	1.2
Background sample taken in 1971, 12 miles from plant	0.9

Summary

Air, water, and soil in the vicinity of the Paducah Gaseous Diffusion Plant were continu-

Table 23. Beta emitter concentrations in environmental water samples, Paducah Plant, January-December 1972

Sample point [a]	Number of samples	Dissolved (pCi/liter)					Number of samples	Suspended (pCi/liter)				
		Maximum	Minimum	Average	Standard	Percent of standard		Maximum	Minimum	Average	Standard	Percent of standard
Ohio River:												
9	11	36	<4.5	<8.1 ± 6.4	[b] 1 000	<0.81	8	<4.5	<4.5	<4.5 (lower limit)	[b] 1 000	< .45
50, 51, 52, 53 composite	11	45	<4.5	<17 ± 13	[b] 1 000	<1.70	8	41	<4.5	<12.4 ± 12	[b] 1 000	<1.2
Big Bayou: [c]												
1	12	248	<4.5	<50 ± 39	[d] 20 000	< .25	9	167	<4.5	<33 ± 26	[d] 20 000	<.17
3	52	834	<4.5	<39 ± 14	[d] 20 000	< .20	39	567	<4.5	<90 ± 40	[d] 20 000	<.45
Mouth of creek:												
21	11	1 782	<4.5	<231 ± 321	[e] 20 000	<1.16	8	108	<4.5	<39.4 ± 29.7	[e] 20 000	<.20
Little Bayou: [f]												
17	52	11 232	41	1 228 ± 452	[d] 20 000	6.14	39	3 276	50	538 ± 196	[d] 20 000	2.69
Ground water: [c]												
11	12	41	<4.5	<9.9 ± 6.5	[d] 20 000	<.05	9	63	<4.5	<21 ± 15	[d] 20 000	<.11
12	12	45	<4.5	<12 ± 5.0	[d] 20 000	<.06	9	18	<4.5	<4.8 ± 3.8	[d] 20 000	<.02

[a] See figure 6.
[b] Kentucky Water Pollution Control Commission regulation WP-4-1 (*14*).
[c] Unclassified.
[d] AEC concentration guide equivalent (thorium-234).
[e] Ohio River Valley Sanitation Commission Pollution Control Standard 70-1 (standard for thorium-234) (*15*).
[f] Unclassified stream on Government property.

ously or periodically sampled during 1972 at the locations shown on figure 6. Analyses for materials known to be in plant effluents were made to provide effluent control information and to determine compliance with applicable air and water quality standards.

The air analyses for radioactivity indicate concentrations at all offsite sampling stations averaged less than 1 percent of the applicable AEC standards.[1]

Soil samples collected to provide historical background data were analyzed for uranium. The results ranged from 1.1 ppm to 2.0 ppm at the AEC property boundary. None of these concentrations would be expected to have a significant impact on the environment.

There was no detectable change in radioactive characteristics of either the Ohio River or ground water attributable to Paducah Gaseous Diffusion Plant operations.

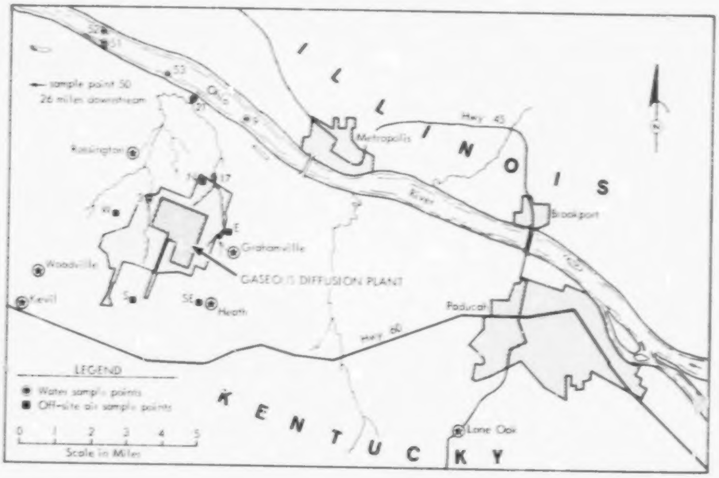
52
51
53
← sample point 50
26 miles downstream
Ohio
21
9
River
ILLINOIS
Metropolis
Hwy 45
N
Rossington
16
17
3
W
E
Grahamville
Woodville
GASEOUS DIFFUSION PLANT
Kevil
S
SE
Heath
Brookport
Paducah
Hwy 60
LEGEND
Water sample points
Off-site air sample points
0 1 2 3 4 5
Scale in Miles
KENTUCKY
Lone Oak

Figure 6. Sampling locations, Paducah Gaseous Diffusion Plant

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(*14*) KENTUCKY WATER POLLUTION CONTROL COMMISSION. Kentucky Water Pollution Control Commission regulation WP–4–1.

(*15*) OHIO RIVER VALLEY WATER SANITATION COMMISSION. Ohio River Valley Water Sanitation Commission (ORSANCO), Pollution control standard number 70–1.

Recent coverage in *Radiation Data and Reports:*

Period	Issue
1971	July 1973

Reported Nuclear Detonations, July 1974

(Includes seismic signals presumably from foreign nuclear detonations)

The U.S. Atomic Energy Commission announced a nuclear test in the yield range between 20 and 200 kilotons was conducted underground July 10, 1974 by the Atomic Energy Commission at its Nevada Test Site.

Not all of the nuclear detonations in the United States are announced immediately, therefore, the information in this section may not be complete. A complete list of announced U.S. nuclear detonations may be obtained upon request from the Division of Public Information, U.S. Atomic Energy Commission, Washington, D.C. 20545.

☆ U.S. GOVERNMENT PRINTING OFFICE: 1974 582-424/1

SYNOPSES

Synopses of reports, incorporating a list of key words, are furnished below in reference card format for the convenience of readers who may wish to clip them for their files.

CALCULATIONS OF DOSES, POPULATION DOSES AND POTENTIAL HEALTH EFFECTS DUE TO ATMOSPHERIC RELEASES OF RADIONUCLIDES FROM U.S. NUCLEAR POWER REACTORS IN 1972. *Office of Radiation Programs, Environmental Protection Agency. Radiation Data and Reports, Vol. 15,* August 1974, pp. 477–482.

Atmospheric emissions of radionuclides during 1972 reported by operators of 14 boiling water nuclear power reactors and 2 pressurized water nuclear power reactors in the United States were analyzed to calculate resulting doses in the general offsite environment. A sector-averaged diffusion equation, using facility generated onsite annual average meteorology, was used to propagate the emissions from the release point out to 81 kilometers. In 1972, 4.88 megacuries of radioactivity were released to the atmosphere from 16 reactors on 13 sites. The resulting whole body population dose was calculated to be 1649 person-rem to a population of 29.2 million people. The potential health effects induced by external radiation from nuclear power plant emissions in 1972 were less than those induced by natural background and occupational radiation exposures.

KEYWORDS: Atmospheric radioactive releases, health effects, population doses, 1972, nuclear power reactors, United States.

RADIOACTIVITY IN BRAZILIAN MINERAL WATERS. *P. L. Hainberger S.J., I. R. de Oliveira Paiva, H. A. Salles Andrade, G. Zundel,* and *T. L. Cullen. Radiation Data and Reports, Vol. 15,* August 1974, pp. 483–488.

Samples of mineral waters from various parts of Brazil were analyzed for their radium content. Radium-226 activity ranged from nondetectable to 94.1 pCi/liter, and radium-228 ranged from nondetectable to 152 pCi/liter.

KEYWORDS: Brazil, radium-226, radium-228, mineral water.

RADIATION DATA AND REPORTS

Volume 15, Number 9, September 1974

Radiation Data and Reports, a monthly publication of the Environmental Protection Agency presents data and reports provided by Federal, State, and foreign governmental agencies, and other cooperating organizations. Pertinent original data and interpretive manuscripts are invited from investigators.

In August 1959, the President directed the Secretary of Health, Education, and Welfare to intensify Departmental activities in the field of radiological health. The Department was assigned responsibility within the Executive Branch for the collation, analysis, and interpretation of data on environmental radiation levels. This responsibility was delegated to the Bureau of Radiological Health, Public Health Service. Pursuant to the Reorganization Plan No. 3 of 1970, effective December 2, 1970, this responsibility was transferred to the Radiation Office of the Environmental Protection Agency which was established by this reorganization.

The Federal agencies listed below appoint their representatives to a Board of Editorial Advisors. Members of the Board advise on general publications policy; secure appropriate data and manuscripts from their agencies; and review those contents which relate to the special functions of their agencies.

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U.S. ENVIRONMENTAL PROTECTION AGENCY
Russell E. Train, Administrator

Reports

HF Spectral Activity in the Washington, D.C. Area

Richard A Tell, John C. Nelson, and Norbert N. Hankin [1]

The results of preliminary study on the spectral activity of the high frequency band from 0 to 100 MHz with emphasis on the 2–22 MHz band segment are presented. In the 0–2 MHz band segment, which includes the AM standard broadcast region, the highest mean number of signals recorded in any one hour was approximately 14.3 that occurred at 1800 e.d.t., the minimum mean number of signals observed was 8.2 occurring at 0200 e.d.t., and the maximum integral relative power density occurred at 1800 e.d.t.

In the 2–22 MHz band, the peak band activity and peak integral spectral power density both occur between 1800 and 2400 e.d.t. The maximum integral power density is about 20 dB greater during this time period than at other times.

For the overall band of 0–100 MHz, the highest activity appears to occur from about 0900 to 1800 e.d.t. There is a lull in activity that occurs in the early morning hours (0200 to 0600 e.d.t.). The inactivity of nonbroadcast sources is generally correlated with the overall band activity. Measurements show that signals of nonbroadcast origin are significantly lower in amplitude than signals in the broadcast bands.

Quantitative determination of ambient radiofrequency (RF) and microwave exposure levels is currently a topic of great interest to individuals concerned with the possible health implications of this form of electromagnetic radiation. Attention to the possible deleterious interaction of nonthermal levels of RF with humans continues to grow (*1*). Due to a lack of definitive measurements on background levels, several fundamental problems persist:

(a) without good, basic information about typical environmental levels of RF and microwave energy experienced by the general populace, it is difficult to efficiently design biological effect experiments which practically relate to day-to-day type exposures,

(b) the interpretation of present day biological research is encumbered due to an incomplete picture of the electromagnetic environment in terms of its amplitude, frequency, and time history characteristics, and

(c) with the ever increasing use of sophisticated electronics in critical situations (e.g., the wearing of cardiac pacemakers and the use of various automotive systems such as electronic ignition, braking, and collision avoidance systems) and an apparent increase in their electromagnetic interference (EMI) susceptibilities, it is important to understand the nature of the electromagnetic environment in which these sensitive devices must exist and reliably operate.

(d) When definitive health effect information on the nonthermal area is available, the electromagnetic environment must be well defined to measure the impact of proposed regulatory standards.

The Electromagnetic Radiation Analysis Branch conducts a program of developing information about the electromagnetic background for these purposes. Under current development by this branch is a semiautomated environmental RF measurement system which will be used to collect data on ambient RF levels. When completed this measurement system will be deployed in the field for data collection and analysis. Prior to its deployment, various sampling approaches have been under consideration.

---

[1] U.S. Environmental Protection Agency, Electromagnetic Radiation Analysis Branch, Office of Radiation Programs, 9100 Brookville Road, Silver Spring, Md. 20910.

This report discusses a preliminary study on spectral activity in the 0–100 MHz region and particularly in the high frequency band segment of 2–22 MHz. The purpose of the study was to develop insight into the time and frequency variations in observed received signal activity. Through such insights, a practical set of sampling criteria can be generated, allowing a more efficient use of the measurement system in collecting field amplitude-frequency data.

The data represented in this report were taken at the Electromagnetic Radiation Analysis Branch's instrumentation facility in Silver Spring, Md., during the period July 31 to August 6, 1973.

Objectives

This study had several specific objectives:

(a) to determine the relative occupancy of the standard AM broadcast band as a function of time of day and to obtain an indication of the relative contribution of all observable signals to the overall spectral intensity in terms of exposure;

(b) to determine some index of the contribution of nonbroadcast signals to the total spectral activity in the 0–100 MHz frequency range; and

(c) to examine the relative occupancy in a segment of the high frequency (HF) band (2–22 MHz) as a function of time of day, directional characteristics of the arriving signals, and frequency.

Measurement equipment

Signals in the HF band are characterized by intermittent occurrence and poor stability; these two characteristics are present because (a) much of the band is used for communication activities which routinely are of an on-off nature, and (b) essentially all of the band is subject to highly variable propagation conditions resulting in significant signal fade. The predominant propagation mode accounting for long distance telecommunications in the HF band is earth-ionospheric reflection which is a function of upper atmosphere ionization density and ionospheric height and thickness. Due to the relatively high dynamic character of HF signals, an adequate data acquisition technique which possesses a high collection speed should be used for maximum accuracy in determining spectral activity. In lieu of having such a system available, which typically would involve an automated operation of a scanning spectrum analyzer through an interface with a minicomputer storage system, our data reported here must be considered as preliminary and used as only semiquantitative indicators of spectral activity.

The measurement system used is diagrammatically illustrated in figure 1. The principal instrumentation consisted of a spectrum analyzer capable of scanning the frequency range of approximately 0 to 110 MHz or any selected segment of this range, an oscilloscopic camera for producing photographs of the visual spectral display from the analyzer, a tracking generator which is useful for determining the center frequency of the scan made by the spectrum analyzer, and a selection of two different antennas consisting of a rotatable planar, log periodic antenna, and a random length, long wire antenna. The log periodic antenna had a nominal gain of 7–12 dBi (isotropic gain) over its frequency range of 6.2 to 30 MHz with a nominal 3 dB beam width varying from 70

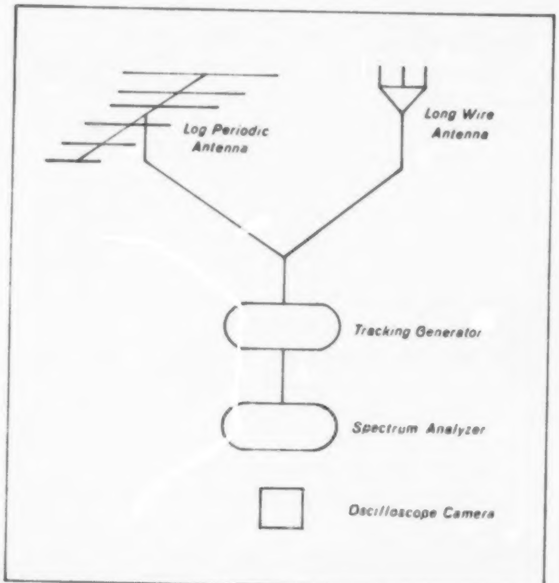


Figure 1. Measurement system diagram

Table 1. Measurement equipment summary

Equipment designation	Model and manufacturer
Spectrum analyzer consisting of:	
Variable persistence display section	Model 141T, Hewlett Packard
110 MHz RF section	Model 8353B, Hewlett Packard
High resolution IF section	Model 8552B, Hewlett Packard
Oscilloscope camera	Model 197A, Hewlett Packard
Tracking generator	Model 8443A, Hewlett Packard
Log periodic antenna	Model LP-1017, Hy-Gain Electronics

to 90 degrees and a front-to-back ratio of 2 dB at 6 MHz to 14 dB at 21 MHz. Table 1 summarizes the specific measurement equipment.

Sampling procedures and data analysis

The method used in data collection consisted of setting up the analyzer for the appropriate frequency range, band width, scan repetition rate, spectral amplitude display range, and connection of the desired antenna at the designated sampling times. A usable spectral display was then generated on the cathode ray tube (CRT) of the analyzer from which a photographic record was made. All photographs and associated control setting information were serialized so that analysis of the data at a later time was orderly.

The measurement scheme outlined in table 2 was used during the data collection for this report. Analyzer band widths were chosen on the basis of being compatible with typical signal band widths found in the various frequency regions investigated. The data obtained through this procedure represent an instantaneous record of spectral activity at a specific time and are thus not results of a long, time averaging technique whereby a continuous flow of spectral data was monitored and maintained over the study period of 6 days. However, due to the rather small time increment between measurements, it was felt that a reasonable indication of gross time-of-day variations in activity could be detected and this proved to be the case as is apparent in the results section.

Table 2. Measurement scheme outline

Frequency range (MHz)	Date (1973) (time e.d.t.)	Antenna[a]	Sample internal (h)	Total measurements	Band width (kHz)
0–100	7/31–8/1 (1200–1200)	L.W.	1	25	
0–100	8/1–8/6 (1400–1200)	L.W.	2	60	
0–2	7/31–8/1 (1200–1100)	L.W.	1	24	3
0–2	8/1–8/6 (1400–1200)	L.W.	2	60	3
2–22	8/2–8/6 (1400–1200)	L.W.	2	48	10
2/22	7/31–8/1 (1200–1200)	L.P.	1	25	10
2/22	8/1–8/2 (1400–1200)	L.P.	2	12	10

[a] L.W., long wire antenna
L.P., log periodic antenna

Analysis of the data was performed by examining the relationship between several parameters, specifically:

(a) the mean relative number of signals observed within a given frequency band whose amplitude exceeded a defined threshold value;

(b) the mean relative power of each signal above a defined threshold value in units of dBm where 0 dBm is equal to 1 milliwatt or the mean relative power density in units of dBm/cm^2, e.g. —10 dBm/cm^2 = 0.1 mW/cm^2;

(c) the subband frequency within the overall frequency scan;

(d) the direction of the rotatable log periodic antenna; and

(e) the time of day in eastern daylight time (e.d.t.).

In all cases, the measured data were presented as signal amplitude-frequency displays with the amplitude information displayed logarithmically such that signal power could be easily compared between signals on a decibel (dB) basis. This is particularly convenient due to the large dynamic range in amplitude values.

A threshold of 52 dB down from the maximum observed signal amplitude was used for counting the standard AM broadcast spectrum data. This represented a level at which the noise level became significant.

The 0–100 MHz scans were analyzed for an indication of the amount of nonbroadcast signal activity by comparing signal counts in the entire 0–100 MHz scan to the number of signals observed within a fixed subband which was established between the high end of the HF band and the low end of the VHF television broadcast band. Within this frequency subband, the principal signal contribution is due to various communication services, notably part of the land mobile service and other two-way radio communication activities. Such observations were made in order to assess impact of intermittent signal services upon the fairly stable, daily exposures from the broadcast sources. This particular comparison was made by finding the ratio of signals counted in the subband to those found in the entire 0–100 MHz band and expressing the results as a percentage. In another case, the ratio of maximum observed signal power in the entire band to that in the subband was determined in an effort to find the relative importance of the exposure from this subband.

For the AM standard broadcast band, an analysis of the effect of individual signals on the total spectral power density was determined. This was accomplished by taking a representative spectral display and expressing the accumulative percent of total integrated spectral power density as a function of the accumulative number of signals in order of increasing power.

Spectral activity in the HF band was high and presented a tedious problem of manually extracting data (both signal count and amplitude) from the spectral photographs because of the large number of signals present. In this case, a sliding threshold was utilized for each subband segment of the 2–22 MHz region measured. Signals were tabulated for each subband on the basis of individual signal distinguishability, the difference in amplitude between the lowest distinguishable signal and the next highest signal complex (possibly a complex of several weak signals escaping frequency resolution by the analyzer), and the threshold selected for that band. Despite the variabilities in the above procedures, overall estimations of integral spectral power displayed within each subband (2 MHz width) are considered accurate to ±30 percent.

Since all data were taken from the standpoint of determining relative activity within various frequency regions, no attempt was made to ascertain in this study, the absolute field intensities from measured signals. Such a determination would require complete characterization of the antenna system used and transmission lines used to connect the antennas with the instrumentation.

Results, 0–20 MHz

Results of spectral measurements in the AM standard broadcast region (0.54–1.6 MHz) are given in figure 2 for the first day of observations wherein measurements were made once per hour. Figure 3 is a plot of similar data collected over a total of 6 days. The principal observations from these two graphs are:

(a) the maximum mean number of signals exceeding the measurement threshold was approximately 14.3 occurring at 1800 e.d.t.;

(b) the minimum mean number of signals

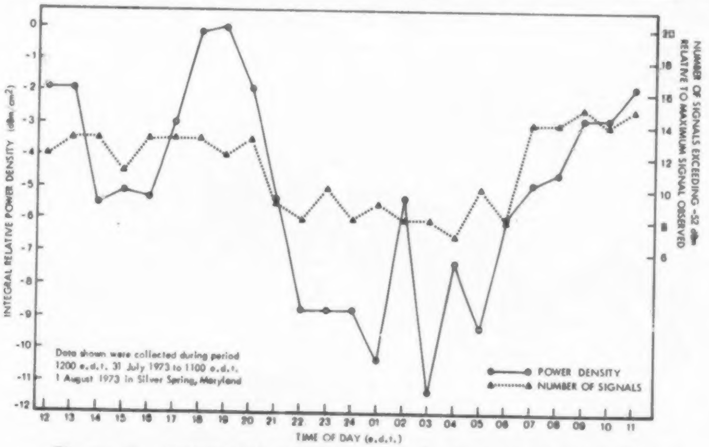


Figure 2. Integrated relative spectral power density in the AM standard broadcast band (1 day)

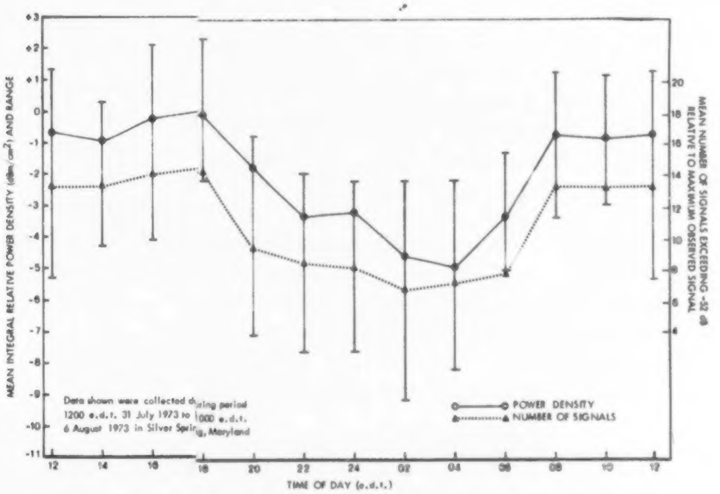


Figure 3. Mean integrated relative spectral power density in the AM standard broadcast band (6 days)

observed was 8.2 at 0200 e.d.t.; and

(c) the integral relative power density tracked the mean number of signals observed with a maximum value occurring also at 1800 e.d.t. while the minimum integral value dropped more than 5 dB from the maximum.

The gradual dropoff in integral power density after 1800 e.d.t. is probably due to deterioration of ground wave propagation at night at our monitoring site. After 2400 e.d.t. several local stations cease operation until approximately 0600 e.d.t. This operational characteristic of the stations is apparent in the dip in figure 3 at 0400 e.d.t.

Figure 4 is an illustrative picture of the spectral display of the 0–2 MHz spectrum from the analyzer. The center frequency for this scan is 1.0 MHz with a frequency dispersion of 200

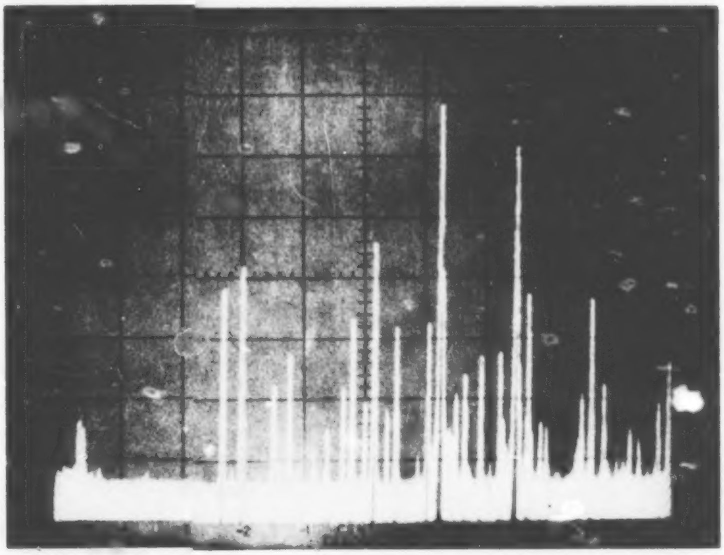


Figure 4. Spectrum analyzer display of 0–2 MHz scan

kHz/division on the CRT. On the far left of the display, the feed-through signal from the spectrum analyzer local oscillator is seen. All other spectral peaks are due to received signals up to 2 MHz. The vertical scale is logarithmic. If the total integral power density of all signals above the threshold is equated to 100 percent, the effect of individual signal contribution to this total may be seen in figure 5. We see that the two strongest signals account for more than 96 percent of the total from all signals detected. This simply means that those stations nearest the monitoring site are usually the predominant input to total RF exposure. In our case, the strongest signal was from a broadcast station located approximately 0.8 km (0.5 miles) away and the second strongest station about 1.6 km (1.0 miles) distant.

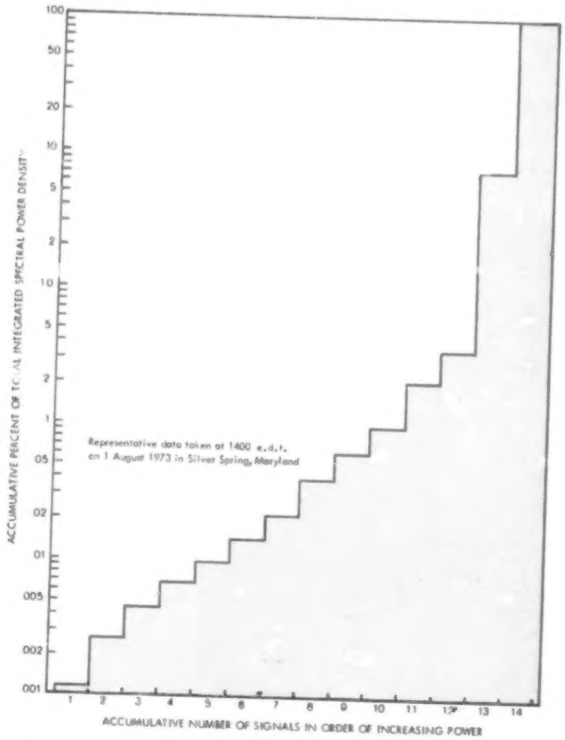


Figure 5. Effect of individual signals on total spectral power density in the AM standard broadcast band

0–100 MHz

Figure 6 reveals the results of the first day's observation of the 0–100 MHz. Figure 7 shows results accumulated over a 6-day period. Principal observations include:

(a) the highest activity in the overall band seems to be from about 0900 to 1700 e.d.t.,

(b) there is a definite lull in activity in the early hours of the morning (0200 to 0600 e.d.t.),

(c) inactivity of nonbroadcast sources is in general correlated with overall band activity,

(d) the highest mean fraction of subband signals to total band signals was approximately 19 percent but the typical value appeared to be more on the order of 10 percent, and

(e) measurement shows that signals of nonbroadcast origin are significantly lower in amplitude than signals in the broadcast or HF bands, typically by more than 50 dB.

2–22 MHz

Figures 8–12 are graphical representations of HF spectral data. Some observations on these results are the following:

(a) there is a general correlation between peak band activity and peak integral spectral power density; however, there seems to be a slight shift in time at which both occur. Both functions peak between 1800 and 2400 e.d.t. The maximum integral power density in this time range is on the order of 20 dB greater than at other times. The slight shift in time (peak power density occurring approximately 2–3 hours later than the peak in activity) appeared to be due to fewer but stronger signals;

(b) HF activity appears to peak two times per day, the major peak occurring at about 2000 e.d.t. and a second, lesser peak at about 0800 e.d.t.;

(c) though adequate statistics are not available, it appeared that maximum spectral power was observed from an easterly direction at most times of the day;

(d) analysis of the relative mean spectral power density both by direction and frequency (figure 10) showed a fairly uniform pattern indicating that the total integral power re-

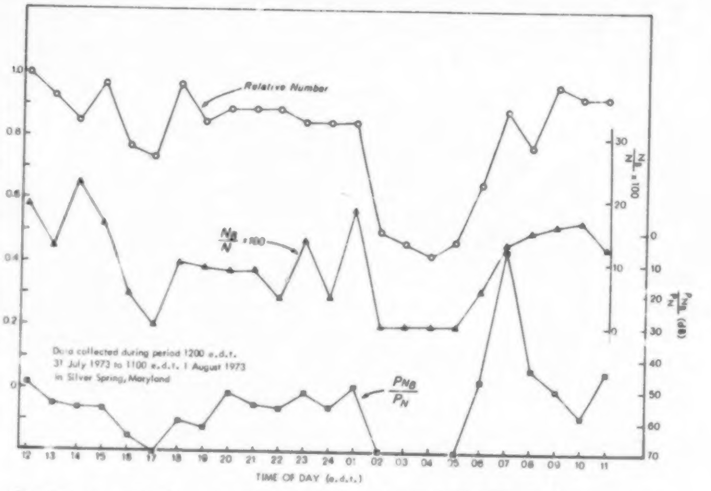


Figure 6. Relative spectral activity in the 0–100 MHz band (1 day)

ceived was approximately uniformly distributed over frequency. One exception noted was a dip in the power received from the east in the 10–14 MHz region of the band;

(e) using a long wire antenna (undefined radiation pattern), figure 11 shows the same bimodal activity and power function at 2000 and 0800 e.d.t. These data have been averaged over the period August 2–6, 1973, and indicate that over this period, the relative band activity approximately doubled at the peak times as compared to other times, while the relative integral spectral power is again 20 dB higher at its peak than otherwise;

(f) with the long wire antenna (figure 12), it was seen that over the August 2–6, 1973, period the highest relative number of signals was in the lowest 2 MHz subband between 2

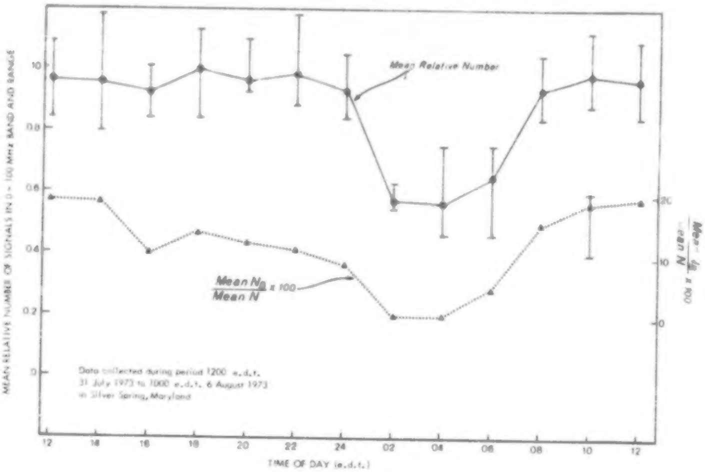


Figure 7. Mean relative spectral activity in the 0–100 MHz band (6 days)

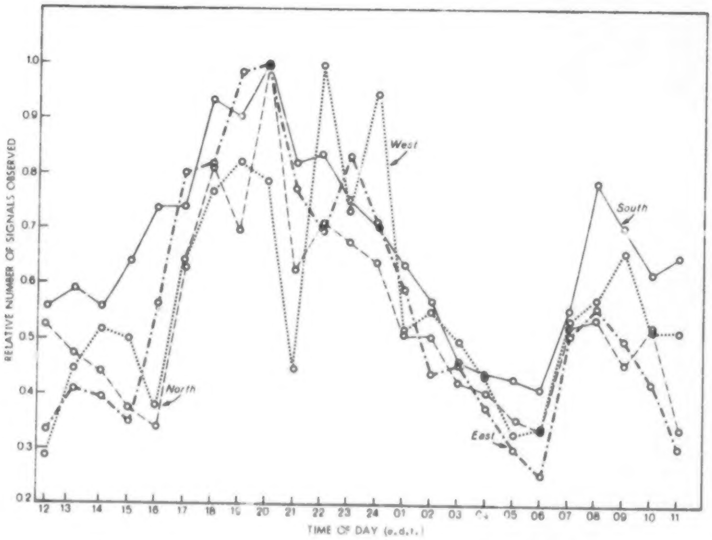


Figure 8. Relative spectral activity in the HF band (1 day, log periodic)

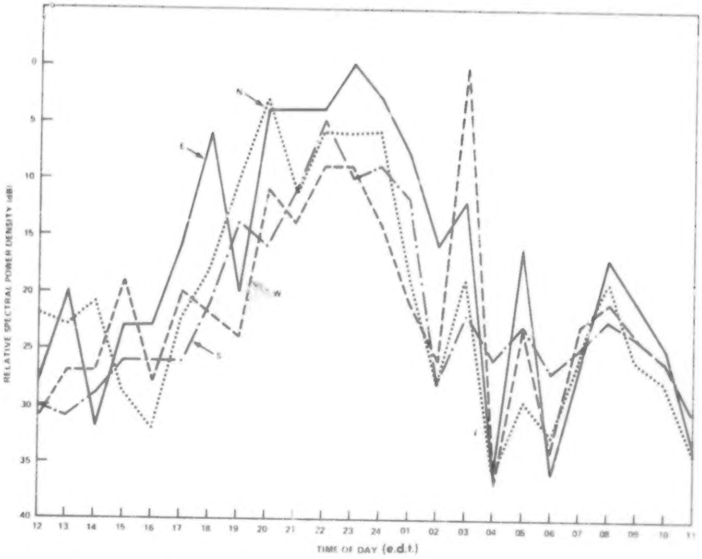


Figure 9. Relative spectral power density in the HF band (1 day, log periodic)

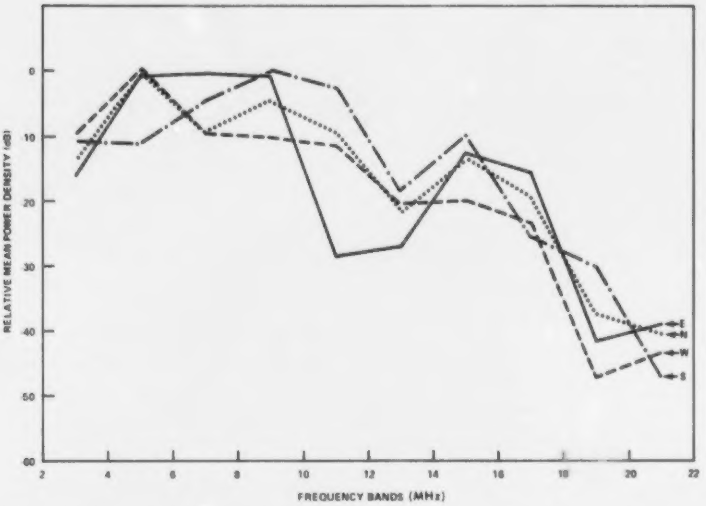
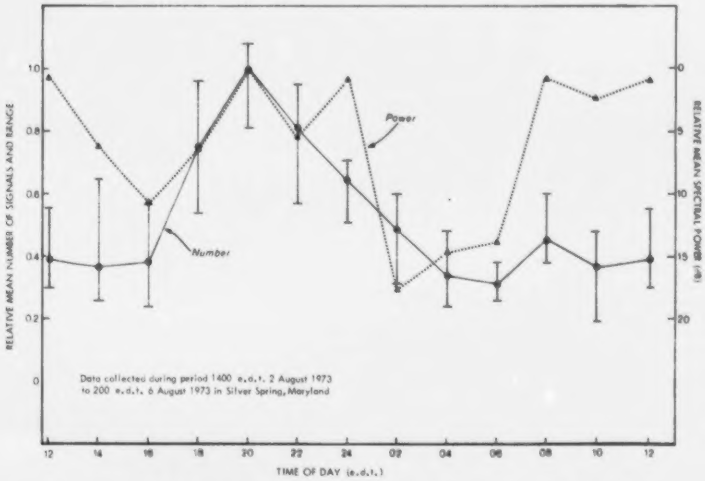


Figure 10. Relative mean spectral power density in the HF band as a function of direction (1 day)



Data collected during period 1400 e.d.t. 2 August 1973 to 200 e.d.t. 6 August 1973 in Silver Spring, Maryland

Figure 11. Mean integral spectral power in HF band (August 2–6, 1973, long wire)

and 4 MHz, and generally decreased as frequency increased. Relative integral spectral power also decreased generally with an increase in frequency but exhibited several relative peaks in the 2–4, 10–12, and 16–18 MHz subbands. These measurements, using the long wire, are representative of resultant values for all directions since no directional information was available on the characteristics of the random length wire; and

(g) the data revealed (data not shown) no noticeable differences in activity or integral signal power as a function of the day of the week.

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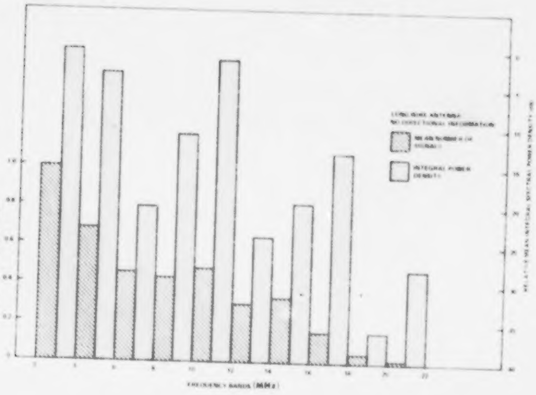

Figure 12. Relative mean spectral power density in the HF band as a function of frequency

Conclusions

Several gross indications of spectral activity in the 0–100 MHz frequency region were obtained which should prove useful for planning future environmental RF measurements:

(a) though not determined on an absolute field intensity basis, indications are that the principal exposure in the 0–100 MHz region is due to sources in the broadcast bands, AM, FM, and TV stations;

(b) signal activity in the HF band is very dynamic and unstable as opposed to the broadcast services;

(c) exposure in the HF band peaks twice per day in Silver Spring, Md., at approximately 2000 and 0800 e.d.t. with the maximum exposure usually occurring about 2000–2400 e.d.t.;

(d) integral HF spectral power is a weak function of direction and thus appropriate isotropic monitoring antennas should be used to insure total signal capture from all directions;

(e) spectral HF exposure is predominantly within the 2–18 MHz part of the band with exposure values falling by approximately 30 dB or more by 22 MHz;

(f) intermittent nonbroadcast or HF activity in the 0–100 MHz region represents only a very slight and essentially negligible contribution to total integral exposure; and

(g) primary exposure, in any band, appears to be a function of the several strongest signals (i.e., after the first few strongest signals are measured, the remaining population of signals contribute essentially nothing in terms of total integral spectral power).

On the basis of this preliminary study, it would be useful to define more accurately the signal and exposure statistics in the various frequency bands, particularly in those bands in which intermittent activity occurs. This would best be accomplished by continuous monitoring and automated data collection by computer assisted instrumentation.

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(*1*) OFFICE OF TELECOMMUNICATIONS POLICY. Program for control of electromagnetic pollution of the environment: the assessment of biological hazards of nonionizing electromagnetic radiation. Executive Office of the President, Office of Telecommunications Policy (March 1973).

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An Evaluation Procedure for a Nuclear Medical Department

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This study presents administrative, health physics, educational, instrumentation and space requirements for departments of nuclear medicine. The data were recorded from answers to a questionnaire and personal interviews with personnel in hospitals with varying bed capacities. Finally, a visual inspection was made of each department by personnel conducting the interview.

A literature survey was conducted to determine if data were available relating to departments of nuclear medicine and certain plant, personnel, educational and equipment parameters that might serve as a guide in evaluating the performances of such departments. Limited data (*1*) to certain aspects of plant and cost (*2*) (or cost/procedure) were available, but not the specifics of the information relating the questions topical to our study. It is within this framework that this study was developed.

The increased and growing uses (*3*) of radiopharmaceuticals in the modern hospital and medical center mandates the establishment of definitive criteria and effective techniques for developing radiation monitoring and evaluating departments using these radioisotopes.

After conducting an initial study of eight radioisotope departments in hospitals of varying bed capacities, over a 12-month period, the authors have attempted to develop a method of evaluating a nuclear medical department. The study encompassed medical, administrative, educational, and health physics parameters and, therefore, includes criteria relative to all three disciplines.

Objectives of the radioisotope department

As a support service, the department provides standard accepted[9] diagnostic in vivo imaging, in vitro tests, and therapeutic procedures on request from the various clinical departments. Originally, radioisotope departments, because of the radiation factors, such as protection, measurements, and dosimetry, came under the direction of radiologists. The current consensus, however, is that the department should be directed by the best qualified specialist. A recent study (*4*) indicated that of the nine hospitals sampled having radioisotope departments, three of the departments are autonomous. Two of these are headed by internists and one by a radiologist. Three are operated under the Department of Radiology, two under the Department of Medicine, and one under the Department of Pathology. Of the five largest hospitals examined in this study, four have radiologists in charge and one is headed by an internist.

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[9] Standard and accepted are defined as the techniques and procedures which have been reviewed by the hospital's Radioisotope Committee and the Human Use Committee as having diagnostic/therapeutic value and approved by the New York City Office of Radiation Control Human Use Committee (not for experimental or research purposes).

Regardless of who directs the department, the use of radiopharmaceuticals involves special care in preparation (*5*), calibration (*6*), administration (*7*), and monitoring to comply with safe and acceptable radiological health standards. For reasons of safety as well as for efficiency, effectiveness, and control, it is, therefore, strongly suggested that radioisotope procedures be performed in a central location rather than fragmented among the various services. Fragmentation reduces clinical and administrative control and usually results in duplication and lack of coordination of personnel, equipment, and supplies.

To meet the objectives of supporting the clinician in the diagnosis and treatment of illness, the radioisotope department must be able to perform, interpret, and report diagnostic test results and therapeutic procedures efficiently[10] and effectively.[11] This support function must be available on a timely basis with consultation to all physicians and departments of the hospital in the following manner.

According to McAfee (*8*), there are eight categories of tracer methodology:

1. dynamics of the steady state,
2. transport across mucous membranes,
3. metabolic pathways and interconversions,
4. biological fate of chemically inert compounds,
5. mineral metabolism,
6. indicator dilution analysis,
7. regional blood flow, and
8. spatial diffusion.

While it is recognized that all radioisotope departments will not perform the same scope or number of services, the techniques for evaluation should be universally applicable.

Patient Dosimetry

Exposure per procedure, cumulative and approval dose record

The following factors should be considered before any radiopharmaceutical is considered for use (*9–11*):

1. adequate review of the desired radioisotopes by the Hospital Isotope Committee considering the appropriateness of the selected isotope.
2. the administered dose,
3. the physical, biological, and effective half-lives,
4. the deposition of the radioisotope to other tissues and organs, and
5. the age and other relevant factors (pregnancy, etc.) of the patient.

All radiation used for diagnosis (x rays and isotopes) have a certain deleterious effect. However, when employed judiciously, the effects of diagnosis (and cure of the patient) must be weighed against these effects. Calculations, experimental evidence and tables are available (*12–14*) so that the clinician and the Isotope Committee can evaluate all of the factors in either approving and performing a procedure or not. The physician and patient must always consider the benefits vs. risks of the disease as opposed to benefit vs. risks from diagnosis and cure. Evidence that these considerations were followed was of singular importance in this study.

Radiopharmaceuticals

Vendors of radiopharmaceuticals are regulated or follow the percepts of the U.S. Food and Drug Administration, U.S. Atomic Energy Commission or State inspection agencies. These vendors maintain quality control and guarantee both the quantity and quality of individual and lot shipments of the radioisotopes supplied to hospitals. However, as with any pharmaceutical used in a hospital, the radioisotope shipment should be calibrated on an individual basis prior to use for both the quantity (millicurie per ml)

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[10] Efficiency is defined as the degree to which a desired result is achieved in the shortest possible time, for the least cost, without being compromised.

[11] Effectiveness refers to the quality of results and the degree to which they enable the clinician to achieve his objectives.

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and quality (other radionuclides). These quality control measurements ascertain the purity of the particular radionuclide to be administered. All data should be logged for reference and accountability.

"Blind" procedures

The use of calibrated samples or two sample techniques as confirmation of in vitro procedures can be employed. For in-house confirmations this may be with or without the knowledge of the person performing the test. The American Society of Clinical Pathology (*15*) has recently established a quality assurance service in nuclear medicine to assist individual laboratories with their internal quality control programs. These are examples of types of quality control techniques that may be employed.

Personnel

The staffing requirements of a nuclear medicine department will vary depending on the size and type of hospital, the number and types of clinical procedures performed and the equipment available (*16,17*). If the hospital has teaching and/or research programs, the isotope department will generally be varied clinically as well as experimentally. The scope and sophistication of the services offered will depend upon the demands and interests of the professional staff, and the resources and goals of the department and the hospital.

Regardless of the numbers of personnel on the staff, each member must have certain minimum education and experience qualifications (*7,18*). The nuclear physician should have as the result of either residency or postresidency training experience in a radioisotope department under the supervision of a trained nuclear medicine specialist. Technical personnel should have at least 2 years of training in posthigh school mathematics, radiological physics, statistics, nuclear detection instrumentation and applied electronics, in addition to radiation protection techniques, etc., geared toward reduction of exposure to patients and personnel (*19*). Further staffing requirements should involve a full-time or consulting medical physicist.

In each case, the personnel selected should possess such other skills and abilities that are identifiable with the department's functions and goals, i.e., clinical, research, teaching (*20*). Technicians may be trained in schools such as Manhattan College (*21*).

Method

The purpose of this evaluation procedure is to have a first technique, a guide or first approximation for a periodic ongoing evaluation of the efficiency and effectiveness of a radioisotope department. An initial literature search yielded some information but did not encompass the varied parameters that were considered essential for the evaluation. In order to accomplish this evaluative procedure, questionnaires were developed in collaboration with administrators, nuclear clinicians, physicists, and technicians.

At current prices, equipment for an adequate, reasonably sophisticated department, providing a broad spectrum of clinical tests, could cost between $125 000 and $175 000. Costs for the services of technologist(s), nuclear clinician, and consulting medical and physics staff could approximate one-half of the initial equipment expenditure per annum.

These costs will vary but must be considered in terms of increased demand as the department develops and offers a greater variety and complexity of tests. Before a radioisotope department is initiated or additional services are added, it is essential that thorough medical and administrative inquiry be made on total costs involved in relation to patient care as well as to the goals and resources of the hospital (*22*).

These questionnaires were then resubmitted to the respective individuals in their areas of specialty, discussed, refined, and then resubmitted for final approval by the same individuals. With this accomplished, the final questionnaire was then prepared and used.

The following broad areas were considered:

1. preparation-storage area,
2. instrumentation,
3. radiopharmaceuticals,

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4. patient data[12] (age, sex, weight, area(s) to be studied, or treated),
5. time and motion,
6. personnel data,
7. nuclear clinical folder data[12] (results of clinical test, effectiveness of test, necessity for repetition of test, etc.),
8. patient folder data[12] (type of radioisotope, type of test, quantity of radioisotope administered, etc.),
9. radioisotope folder-clinical analysis[12] (was the test of clinical significance to the requesting physician, and/or did it serve as a link for further diagnosis, etc.), and
10. radioisotope department broad questions.

Onsite visits were made to each of the hospitals studied. Personal discussions were held with the Directors of Nuclear Medicine, staff and/or consulting physicist(s), senior technologists, and the administrator of the department.

Survey Findings

Space

A modern clinical radioisotope facility requires approximately 37 m² (400 square feet) of operational area exclusive of office, secretarial, dressing, and waiting room space. This area should be divided to provide for radiosotope and clinical preparation, isotope storage, calibration and health physics services. In addition, two or more patient examining rooms are needed to contain the various imaging equipment.

Table 1 presents the survey findings with respect to overall space allocations for the eight hospital isotope departments studied (200 to 1000 beds). For the small hospital (200 beds), this operational space was 30 m² (320 square feet) with an additional 46 m² (490 square feet) for other space requirements. In contrast, a 1000 bed hospital had 100 m² (1100 square feet) of operational space with an additional 86 m² (930 square feet) devoted to other space requirements.

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[12] Not reported in this study but it is the basis of a separate administrative paper.

Table 1. Summary findings of radioisotope audit area requirements

	Hospital							
	1	2	3	4	5	6	7	8
Number of beds	400	350	200	600	300	200	400	1 000
Approximate area (m² in radioisotope department):								
Preparation area	9.2	9.2	7.4	7.4	9.2	5.6	6.5	14
Storage area	2.3	2.8	7.4	3.7	6.5	2.3	6.5	9.2
Supply area	2.3	2.3	1.9	2.3	2.8	2.8	9.2	23
Imaging:								
Rectilinear	12	14	10			15	19	19
Camera	12	20.4		13.0	28		19	28
Health physics area	7.4	7.4	2.8	5.6	7.4	2.8	4.6	9.2
Subtotal	45.2	56.1	29.5	32.0	53.9	28.5	64.8	102
Waiting room	7.4	5.6	4.6	6.5	9.2	5.6	9.2	9.2
Conference room	9.2	9.2	6.5	11	9.2	7.0	9.2	14
Reading room	7.4	14	9.2	9.2	9.2	7.4	7.4	9.2
Physician's office	14	14	11	11	23	11	10	14
Physicist's office	[a] 14	[a] 14		9.2	[a] 11			23
Lead technician area	4.6	4.6	4.6	6.5	6.5	4.6	7.4	7.4
Secretary area	9.2	16.7	9.2	9.2	9.2	7.4	9.2	9.2
Subtotal	65.9	78.1	45.1	62.6	77.3	43.0	32.4	86.0
Total area	110	134	75	95	131	72	117	188
Radioisotope area in a single location	yes	yes	yes	yes	yes	no	yes	yes

[a] Shared room.
[b] Two secretaries.

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Table 2. Summary findings of radioisotope audit: instrumentation

	Hospital							
	1	2	3	4	5	6	7	8
Imaging:								
Rectilinear:								
Age (years)	7	5	2	------	------	1	5	5
Purchase or lease	P	P	P	------	------	P	P	P
Crystal size (cm)	13	13	8	------	------	8	13	13
Number available	1	1	1	------	------	1	2	2
Calibrated	Daily	Daily	Daily	------	------	Daily	Daily	Daily
Down time/yr (d = days)	3 d	1 d	5 d	------	------	1 d	2 d	1 d
Camera								
Age (years)	5	4	------	4	5	------	1	5
Purchase or lease	P	P	------	P	P	------	P	P
Number available	1	1	------	1	1	------	1	1
Calibrated	Daily	Daily	------	Daily	Daily	------	Daily	Daily
Down time/yr (d = days)	• 90 d	3 d	------	4 d	3 d	------	2 d	3 d
Radioisotope calibrator:								
Age (years)	3	2	2	3	2	1	3	3
Purchase or lease	P	P	P	P	P	P	P	P
Number available	1	1	1	1	1	1	1	1
Calibrated	Daily	Daily	Daily	Daily	Daily	Daily	Daily	Daily
Down time/yr (d = days)	0 d	1 d	1/2 d	3 d	5 d	1 d	1 d	1 d
Scalers:								
Age (years)	6–10	8	2	5	3–7	1	3–8	4–10
Purchase or lease	P	P	P	P	P	P	P	P
Number available	2	1	1	1	3	1	3	5
Calibrated	Daily	Daily	Daily	Daily	Daily	Daily	Daily	Daily
Down time/yr (d = days)	2 d	1 d	1 d	1 d	3 d	1 d	3 d	5 d

• Budgetary considerations, a limiting factor.

Equipment

Table 2 summarizes equipment available in each hospital. In only one hospital, which had 250 beds, was spectral analysis performed for the gamma emitters to determine if other radioisotopes were present. All departments had and used a radioisotope calibrator. All departments owned rather than leased their equipment. One of these hospitals did, however, lease the proposed equipment for one or more months prior to purchase in order to determine equipment suitability for the department.

One radioisotope department had a down-time of over 90 days for the gamma camera. This was because of initial failure to establish adequate temperature controls for the crystal which should have been considered as part of the initial capital costs.

Health physics

Table 3 summarizes the basic health physics data accumulated. It is interesting to note that the pocket ionization chamber was not used in a single radioisotope department. Thermoluminescent dosimetry (TLD) was routinely in use in two institutions, with one of these using TLD's for the finger monitoring by personnel. Radiation posting procedures were correctly observed in varying forms in all departments. Lead cubicles and/or containers containing the isotopes were properly identified.

All radioisotopes were logged; for seven of the eight radioisotope departments, the logging was in a looseleaf folder. The eighth department had a bound book. All radioisotope departments had a formal isotope committee and a designated radiation safety officer.

Table 3. Summary findings of radioisotope audit: health physics

	Hospital							
	1	2	3	4	5	6	7	8
Personnel monitoring:								
All radioisotope personnel	yes	yes	yes	yes	yes	yes	yes	yes
Film badges used	yes	yes	yes	yes	yes	yes	yes	yes
Thermoluminescent dosimetry	no	yes	no	no	no	yes	no	no
Pocket ionization chamber	no	no	no	no	no	no	no	no
Preparation area:								
Radiation posting	yes	yes	yes	yes	yes	yes	yes	yes
Shielding of radioisotopes	yes	yes	yes	yes	yes	yes	yes	yes
Radioisotope calibrator	yes	yes	yes	yes	yes	yes	yes	yes
(available)	yes							
Log-in, log-out radioisotopes		yes	yes	yes	yes	yes	yes	yes
Emergency procedures posted	yes	yes	yes	yes	yes	yes	yes	yes
Survey equipment available:								
Number available	1	1	3	2	2	2	3	3
Number functioning	1	1	3	2	2	2	2	2
Calibrated	(a)	(a)	(a)	(a)	(a)	(a)	(a)	(a)
Storage area:								
Radioisotope stored in:								
Adequate containers	yes	yes	yes	yes	yes	yes	yes	yes
Cubicles	yes	yes	yes	yes	yes	yes	yes	yes
Other								
Log of stored radioisotopes	yes	yes	yes	yes	yes	yes	yes	yes
Water disposal:								
Commercial service	yes	yes	yes	yes	yes	yes	yes	yes
Log of disposal	yes	yes	yes	yes	yes	yes	yes	yes
Radioisotope committee:								
Functioning	yes	yes	yes	yes	yes	yes	yes	yes
Minutes available	yes	yes	yes	yes	yes	yes	yes	yes
Radioisotope shipments:								
Radioisotope returned within last 2 years	no	yes	yes	no	no	yes	yes	yes
Radioisotope returned within last year	no	no	no	no	no	no	no	no
Quality control:								
Spectral analysis performed:								
Routinely	no	yes	no	no	no	no	no	no
In doubtful cases	no	yes	no	no	no	yes	yes	yes
Radiation safety officer (RSO):								
Designated	yes	yes	yes	yes	yes	yes	yes	yes
Is RSO:								
Clinician	no	no	no	no	no	no	no	no
Physicist	yes	yes	yes	yes	yes	yes	yes	yes
Lead technician	no	no	no	no	yes	no	yes	no

[a] All functioning survey meters were calibrated within the last year.

All eight hospitals had the consulting physicist as the radiation safety officer, a full-time nuclear technologist serving as his immediate representative. The technologists serving as the alternate for the health physicist did have additional formal and practical training required for the specific job.

Education

The educational backgrounds of all personnel are summarized in table 4. In the case of the nuclear clinicians, all had their specialty board certifications. Seven of the eight directors were certified by the American College of Radiology and one by the Board of Internal Medicine. One director held certification in the ACR and American Board of Nuclear Medicine. In two of the smaller hospitals just initiating a nuclear medicine department, the physician in charge spent from one-quarter to one-fifth of his weekly time in the department. Both of these clinicians had indicated that, as the patient load increased, either they or their delegated physician would spend additional time until there was a full-time nuclear technician.

In six hospitals there was more than one physician with responsibility for nuclear medicine, their total aggregate time being more than 40 hours per week. All hospitals had medical and/or health physicists serving in a consulting capacity. One of the hospitals had a full-time physicist. Only three of the eight physicists were certified, and this was by the American College of Radiology. All technologists had high school diplomas. A number of both the lead technologists and staff technologists had

Table 4. Summary findings of radioisotope audit: educational backgrounds

	Hospital							
	1	2	3	4	5	6	7	8
Physician:								
Number available	2	2	1/2	1/2	1	1/4	1	3
Board certified	yes	yes	yes	yes	yes	yes	yes	yes
Which board [a]	ACR	ACR, ABMN	ACR	ACR	ACR	ACR	ABIM	ACR
Years of experience in nuclear medicine	[b] 4	[b] 6	3	5	5	1	6	[b] 10
Total number of h/wk devoted to nuclear medicine	40	40	20	20	40	10	40	90
Physicist available:								
Part-time	yes	yes	yes	yes	yes	yes	yes	no
Full-time	no	no	no	no	no	no	no	yes
Board certified	no	no	no	yes	no	no	yes	yes
Which board				ACR			ACR	ACR
Years of experience:								
In medical physics	20	22	20	20	8	20	15	15
In nuclear medicine (part of total time of medical physics above)	4	2	5	5	8	5	7	10
Number of h/wk devoted to nuclear medicine	15	10	2	8	10	2	4	30
Lead technologist:								
Licensed in nuclear medicine	yes	no	no	no	no	no	yes	yes
High school diploma	yes	yes	yes	yes	yes	yes	yes	yes
Associates degree	yes	(c)	(c)	no	(c)	no	yes	yes
Bachelor's degree	(c)	no	no	no	no	no	no	yes
Years of experience:								
Nuclear medicine	7	5	3	3	8	1	6	8
Technologists (excluding lead):								
Number available	2	3	0	0	2	0	3	4
Licensed in nuclear medicine	0	0	0	0	0	0	0	1
Number with high school diploma	2	3	0	0	2	0	3	4
Number with associate degree	[c](1)	[c](3)	0	0	[c](1)	[c](1)	[c](2)	2
Number with bachelor's degree	0	0	0	0	0	0	0	0

[a] ACR, American College of Radiology
ABNM, American Board of Nuclear Medicine
ABIM, American Board of Internal Medicine.
[b] Average number of years.
[c] In progress.

or were preparing for an associate or higher degree (*21*).

Time and motion per procedure

Table 5 shows a time and motion study available from one hospital which had attempted to assign average time factors for each of the examinations it had been conducting. It should be noted that the other nuclear medical departments expressed concern for the time and motion aspects and did state that they had general figures regarding the average time per procedure but that it had not been formalized. While it is realized that newer instrumentation or revised radiopharmaceuticals will replace existing systems, the table presented does provide a guide to total time employed per procedure. Further, it is realized that each radioisotope department will develop its own time and motion study. This guide may be at variance with the table presented here; however, such a table will provide the technician, clinician and administrator with an approximation as to average time to be anticipated per procedure.

Summary

A broad based questionnaire was prepared by a team composed of administrators, radiologist, physicists and technologists, dealing with a number of parameters in nuclear medicine. Summary data for a number of these areas are presented in this report.

Future work

It is realized that this survey, reported here in part, is a first attempt to relate a number of medical, administrative, technical, health physics, and patient parameters. It is hoped that from this initial effort, refinement, criticism and revisions will result in a final audit guide applicable to all nuclear medicine departments.

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Table 5. Summary findings of radioisotope audit time and motion; in vitro and camera procedures

Type of examination	Time to prepare patient set-up[a] (minutes)	Time to prepare radioisotope[b] (minutes)	Procedure time[c] (minutes)	Level of difficulty[d]	Number of procedures (minutes)	Total time[e] (minutes)
Brain[f]	15	6	6	6	5 (30 min)	[e] 51
Liver[h]	15	20	5	5	4 (20 min)	[e] 55
Renal scan[i]	15	15	15	3	3 (45 min)	[e] 75
Renogram	15	6	30	2	1 (30 min)	[e] 56
Spleen	15	20	5	2	3 (15 min)	[e] 50
Heart[f]	15	6	6	4	3 (18 min)	[e] 39
Schilling test	15	10	45	2	1 (45 min)	[e] 70
Placenta	15	6	10	2	2 (20 min)	[e] 41
Blood volume	20	10	30	3	1 (30 min)	[e] 60
Lung[k]	15	6	7	6	6 (42 min)	[e] 63
RBC	55	15	20	5	2 (40 min)	[e] 110
T-3's	120	15	30	3	2 (60 min)	[e] 195
T-4's	180	15	15	6	2 (60 min)	[e] 255
Thyroid uptake	10	10	10	2	2 (20 min)	[e] 40
Bone[m]	35	6	20	10	4 (80 min)	[e] 121
Fat absorption	30	15	120	5	1 (120 min)	[e] 165
Thyroid scan	15	6	15	3	1 (15 min)	[e] 36
Liver function	15	6	15	5	5 (75 min)	[e] 96
^{59}Fe kinetic	30	6	15	5	6 (90 min)	[e] 156
Digoxin[n]	90			8		[e] 180
Angiotensin[n]	60			10		[e] 360

[a] Prepare patient from the time patient comes in room for scan. This is an *average time*, some patients are easier to work with, some more difficult.
[b] Prepare radioisotope: to take radioisotope from storage area, or withdraw liquid radioisotope solution (calibrate liquid quantity).
[c] Actual time from administration of radioisotope to obtaining data and confirming results obtained, prior to the release of patient.
[d] Level of difficulty: 1, the easiest; 10, the most difficult.
[e] Transportation time of patients was not included in these estimates. One can assume 30–40 minutes delay (average 30 minutes).
[f] Dynamic study performed with brain and heart scans. One film every 3 seconds for a total of eight films in 24 seconds.
[g] This does not include any time (estimate from 5 minutes to 1/2 hour) to obtain physician. Procedure times are subject to change with the development of new agents.
[h] Agent used was technetium-99m sulfur colloid.
[i] Agent used was technetium-99m D.T.P.A.
[k] Agent used was iodine-131 M.A.A.
[m] Agent used was strontium-85.
[n] Time for six tests.

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Significance of Stable Iodine-127 in Milk

William J. Kelleher and Harvey R. Prins [1]

The unexpected high concentrations of stable iodine in milk found when studying the specific activity concept for iodine-129 around a nuclear fuels reprocessing plant led to an evaluation of the use of iodine-129 to iodine ratio in milk samples to calculate population doses. In order to use specific activity to calculate thyroid dose, it will be necessary to establish values for the concentration of iodine in thyroids. If a constant concentration of iodine in the thyroid is assumed and there is a high enough concentration of iodine in the milk to be able to assume that milk is the only source of iodine in the thyroid, a relationship between thyroid dose and iodine-129 to iodine or iodine-131 to iodine ratios can be developed. The use of specific activity in milk to determine dose will have the greatest application in evaluating the man-rem dose from the discharges of iodine-129 from fuel processing plants.

In the calculation of yearly dose to the thyroid of a member of the public from the ingestion of milk containing radioiodine, the concentration of stable iodine in the milk is usually ignored. An uptake factor of 0.3 in accordance with International Commission on Radiological Protection (ICRP) (*1*) recommendations is generally used. However, if the milk contains a sufficient concentration of stable iodine-127, the thyroid uptake factor for iodine could be less than 0.3. If milk is the only source of iodine in the body, then the ratio of iodine-131 or iodine-129 to total iodine in the human thyroid could not be higher than that found in the milk.

Specific activity concept

The use of specific activity, iodine-129/iodine, has been discussed by Bryant (*2*), Russell and Hahn (*3*), and Tadmor (*4*) in evaluating the potential hazards to the public from iodine-129 released at fuel reprocessing plants. The authors discussed the assumption that the iodine-129 and iodine-127 continuously released would reach equilibrium with the natural iodine-127 present in the environment and the maximum possible dose to the thyroid might be predicted from the iodine-129 to iodine ratio found in environmental samples. A critical environmental pathway, milk, might be evaluated by the conservative assumption that a continuous routine atmospheric release of iodine-129 would reach equilibrium with naturally occurring iodine in the air and the ratio of iodine-129 to iodine would reach equilibrium throughout the environmental pathways to milk. The maximum possible dose to the thyroid from deposition on pasture land would be unlikely to exceed the dose predicted by the iodine-129 to iodine ratio in the air. The authors recognized that sources of iodine-127 other than air could lower the ratio, but no natural environmental method for increasing the ratio could be predicted.

The finding of iodine-129 in milk and other environmental samples around the Nuclear Fuel Services (NFS) Reprocessing Plant in New York State has been reported by the New York State Department of Environmental Conservation (NYSDEC) (*5,6*). The U.S. Environmental Protection Agency (EPA) also conducted cooperative studies around NFS (*7,8*) and confirmed the presence of iodine-129 in milk and other samples due to atmospheric releases. EPA provided funding to the NYSDEC

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[1] New York State Department of Environmental Conservation, Albany, N.Y. 12201.

Table 1. Iodine-127 concentrations in milk

Farm	Date	^{127}I (μg/liter)	Farm	Date	^{127}I (μg/liter)	Farm	Date	^{127}I (μg/liter)
14	8/14/71	[a] 159	31	2/ 6/73	233	51	3/ 6/73	2
	12/ 4/72	[b] 4 626		6/12/73	[c] <1		4/18/73	<1
	12/14/72	610		8/14/73	27		7/17/73	39
	1/ 7/73	417		9/19/73	42		10/25/73	45
	2/ 6/73	371		10/25/73	21		11/29/73	78
	3/ 6/73	232		11/29/73	185		12/27/73	1 639
	4/18/73	354	43	12/ 4/72	285	68	1/ 7/73	243
	5/ 9/73	433		3/ 6/73	31		4/18/73	59
	6/12/73	65		4/18/73	273	96	1/ 7/73	5 670
	7/17/73	49	45	8/14/72	74		2/ 6/73	2 183
	9/19/73	100	45A	2/ 6/73	390		6/12/73	1 099
	10/25/73	45		3/ 6/73	706		7/17/73	3 587
	11/29/73	72		9/19/73	162		8/14/73	960
	12/27/73	418	46	5/ 9/73	344		9/19/73	1 104
	2/ 5/74	1 124	49	5/ 9/73	1 292		10/25/73	1 418
31	12/ 4/72	98	50	5/ 9/73	1 827		11/29/73	264
	1/ 7/73	223		8/14/73	354		2/ 5/74	721

Errors of 2 standard deviations are approximately:
[a] ±7 percent.
[b] ±2 percent.
[c] ±100 percent.

to support a further study of iodine-129 in milk and requested an evaluation of the specific activity concept as applied to the NFS site. The study required that both iodine-129 and iodine-127 be measured in milk by neutron activation. The results of the study were reported by Kelleher and Michael (*9*).

Iodine-127 in milk around a fuel reprocessing plant

The NFS plant was shut down in November 1971, and probably no significant releases of iodine-129 occurred after that time. The study indicated no buildup of iodine-129 in the local milk supplies because of the weathering of previously deposited iodine-129. The study revealed unexpected high concentrations of iodine-127 in many of the milk samples and a wide range of iodine-127 in milk from <1 μg/liter to 5 700 μg/liter. Table 1 gives the concentrations observed at different farms.

The difference in iodine-127 concentrations in milk from one farm to another around the NFS plant can be accounted for by varying farming practices. One of the most important factors is the amount of medicated or trace mineralized salt containing iodine-127 added to the cow's diet (*9*). An investigation of iodine-127 concentrations in milk supplies in other areas of New York State and their variances with the season is planned to ascertain if the findings pertaining to the milkshed around NFS are similar throughout the State. Information from a few interviews outside the NFS area indicate that ethylene diamine dihydroiodide, EDDI, is routinely used by many dairy farmers in the State to prevent foot rot which is a problem in cold damp climates.

The concentrations of iodine-127 in cow's milk around the NFS area are related to outside sources of iodine-127, farming practices, and seasonal variations and have little relationship to natural iodine in the air. Therefore, the use of iodine-129 to iodine ratio in air assuming equilibrium conditions to obtain dose from the ingestion of milk appears to be highly conservative. However, the ratio of iodine-129 to iodine actually found in milk samples to assess the maximum possible yearly thyroid dose from consumption of milk might be used if the concentration of iodine in the milk is high enough to assume it is the only source of iodine found in the thyroid.

Proposed U.S. Atomic Energy Commission (AEC) guidelines (*10*) for light-water nuclear power plants require that iodine-131 in milk be measurable down to a level of 0.5 pCi/liter in order to demonstrate that the maximum possible infant thyroid dose will not exceed 15 mrem per year. The AEC guide (*11*) for analysis of iodine-131 in milk requires that iodine be added and the chemical yield determined. In order to find chemical yield, the amount of iodine already in the milk should also be determined. It is expected that the AEC will also develop guidelines for iodine-131 and iodine-129 at fuel reprocessing plants with similar require-

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ments for detection of low levels of radioiodines. In neutron activation analysis for iodine-129, iodine-127 can also be readily determined.

Evaluation of iodine-127 in milk

Since the tests for radioiodine in milk may also require a total iodine determination, it is appropriate to examine the iodine-129 or iodine-131 to iodine ratio to ascertain what the maximum possible dose could be. The ICRP (*1*) model for dose determination and the FRC (*12*) recommendations as to dose from ingestion of iodine-131 will be used. Matuszek et al. (*13*) have recommended a re-evaluation of the dosimetry of iodine-129 in the thyroid gland particularly the effect of high-LET Auger electrons. The purpose of this paper is to look at possible uses of specific activity on individual milk samples and not to develop changes in relation between thyroid burdens and doses recommended in the 1959 ICRP Report (*1*).

The FRC and ICRP data to be used in the calculations of ratios are as follows unless otherwise stated:

m = mass of thyroid = 2 grams for infant, 20 grams for adult,
T_b = biological half-life of iodine in thyroid = 138 days,
f_w = fractional uptake by thyroid gland = 0.3,
T_e = effective half-life = 7.6 days for iodine-131 and 138 days for iodine-129,
t = time in days,
C = concentration of iodine in thyroid in $\mu g/g$ = 350 $\mu g/g$ for adult or child (note that C is not used in the 1959 ICRP report to determine maximum allowable concentrations),
I = μg of iodine,
I_d = daily intake of iodine (μg/day),
ξ = effective absorbed energy per disintegration in the thyroid gland (MeV) = 0.22 for iodine-131 and .068 for iodine-129,
P_d = daily intake of radionuclide in pCi/day,
R = allowable weekly dose in rem/week, and
D = allowable yearly dose in mrem/year.

Iodine-129 to iodine ratio

The use of a radioiodine to iodine ratio to predict yearly thyroid dose has its greatest application for the long-lived radionuclide iodine-129 where the physical half-life of 17 million years results in the effective half-life and biological half-life being the same. Therefore, the rate of elimination of iodine-129 and iodine from the thyroid are the same simple exponential function of time used in the ICRP model.

In the proposed use of specific activity in milk to determine thyroid dose, the iodine-129 to iodine ratio in the thyroid is assumed to be the same as in the milk. The concentration of iodine-129 in the thyroid is determined by multiplying iodine-129 to iodine ratio in the milk by the concentration of iodine "C" in the thyroid. Dose is then determined in the conventional manner from the thyroid burden of iodine-129 per mass of thyroid tissue. The specific activity method of dose calculation presently proposed depends on a constant "C", the concentration of iodine in the thyroid, and, as will be demonstrated, the maximum possible dose from iodine-129 can be calculated without using the uptake factor, biological half-life, or the amount of milk consumed.

In order to illustrate the application of the ratio concept, the commonly used method of dose determination will be used which assumes an uptake factor of 0.3.

The daily requirement of an infant, assuming equilibrium where the rate of intake equals the rate of elimination, would be:

$$I_d = \frac{0.693\, mC}{f_w\, T_b} = \frac{(0.693)\ (2)\ (350)}{(0.3)\ (138)} = 11.7\ \mu g/\text{day} \qquad (1)$$

The allowable intake of iodine-129 not to exceed 0.5 rem per year dose to the thyroid, assuming equilibrium, would be as follows:

$$P_d = \frac{2.8 \times 10^3\, mR}{\xi\, f_w}\ \frac{0.693}{T_e} = \frac{(2.8 \times 10^3)\ (2)\ (9.61 \times 10^{-3})\ (0.693)}{(.068)\ (0.3)\ (138)} = 13.2\ \text{pCi/day} \qquad (2)$$

Equilibrium was assumed for total iodine and iodine-129 because the rate of elimination from the thyroid is the same for both and it is assumed that the thyroid was only exposed to the same iodine-129 to iodine ratio. Also, it should be noted that, at equilibrium, the dose to the thyroid for a given continuous daily intake of iodine-129 will be at the maximum.

If a child drinks 1 liter per day, then the allowable ratio of iodine-129 to iodine in milk so as not to exceed 0.5 rem per year to the infant thyroid is:

$$\frac{^{129}\mathrm{I}}{\mathrm{I}} = \frac{13.2\ \mathrm{pCi/liter}}{11.7\ \mu\mathrm{g/liter}} = 1.1\ \frac{\mathrm{pCi}}{\mu\mathrm{g}} \qquad (3)$$

If equations (1) and (2) were to be solved simultaneously by dividing P_d by I_d, R would be related to the ratio as follows:

$$R = \frac{\xi C}{2.8 \times 10^{3}}\ \frac{P_d}{I_d}\ \text{and}$$

$$D = 18.6\ \xi C\ \frac{^{129}\mathrm{I}}{\mathrm{I}}\ \ \text{in mrem/yr} \qquad (4)$$

As previously explained, the formula simply states that the concentration of iodine-129 in the thyroid is determined by multiplying the iodine-129 to iodine ratio in milk by the concentration of iodine in the thyroid, and dose is determined from the burden of iodine-129 per mass of thyroid. For $C = 350\ \mu g/g$, $\xi = .068$ MeV and iodine-129 to iodine ratio in milk used $D = (18.6)\ (.068)\ (350)$ iodine-129/iodine $= 440$ iodine-129/iodine.

The major advantage of the specific activity for iodine-129 in milk is that uptake factor, biological half-life, amount of milk consumed, amount of iodine in the diet do not enter the dose calculation. The major disadvantage is that the dose can be underestimated if the value of "C" chosen is too low or if "C" increases as the amount of iodine in the diet increases. If specific activity is to be used, it will be important to establish a relationship between "C" and iodine in the diet.

Le Blanc et al. (*14*) found that normal adult thyroid tissue obtained from autopsy specimens was 980 μg of iodine per gram of thyroid. The authors attributed a lowering of the uptake factor for iodine-131 to an increase of iodine in the diet in the Houston, Tex., area. In a Battelle report (*15*) where different values for "C" were used for four age groups, it was concluded that the limiting iodine-129 to iodine-127 ratio would be based on the adult thyroid because of a higher "C" for the adult (350 $\mu g/g$) as compared to 90 $\mu g/g$ for the one year old.

The use of specific activity for iodine-129 in milk is not recommended for the design or control of nuclear fuel reprocessing plants. A decision on the part of the dairy farmer to eliminate the use of EDDI (ethylene diamine dihydroiodide) in the cow's diet could drastically lower the iodine-127 found in the milk. The present model for dose assessment using an uptake factor of 0.3 and biological half-life of 138 days appears to be appropriate for design and control purposes.

Specific activity of iodine-129 in milk can be used for estimating the actual impact of an operating nuclear facility. This is especially important when one is comparing alternate environmental pathways to determine which source of radioiodine, inhaled or ingested, gives the greatest thyroid dose. The actual aggregate man-rem thyroid dose from iodine-129 as calculated from specific activity will be much less than the value calculated using the conventional model in those areas where the dairy farmers add EDDI to the diet of cows. Analyses of milk from individual dairy farms and pooled milk from milk receiving plants will give the necessary data to use specific activity to determine man-rem dose.

An example of the use of the ratio concept is given in table 2 where an allowable dose of 500 mrem/year and a value of $C = 350\ \mu g/g$ are assumed. A comparison is made to an extrapolation of the FRC recommendation for iodine-131 to iodine-129. The use of a value of $C = 1\,000\ \mu g/g$ instead of $350\ \mu g/g$ would require that the dose be multiplied by a factor of 2.9 or the allowable concentration reduced by a factor of 2.9 when using specific activity to calculate dose.

The use of the ratio to predict dose from iodine-129 below 10 μg/liter of iodine in the

Table 2. Allowable concentration iodine-129 versus concentration of iodine

(For 500 mrem per year dose and $C = 350\ \mu g/g$)

Actual μg iodine/liter of milk	Allowable concentration of iodine-129 (pCi/liter)	
	From ratio $^{129}I/I$	From FRC [a]–ICRP
10	11	16
20	23	16
40	45	16
100	110	16
500	570	16

[a] The Federal Radiation Council's recommendations for iodine-131 intake were extrapolated to iodine-129 using 80 pCi/liter as an allowable iodine-131 concentration and multiplying this by the ratio of maximum permissible concentrations of iodine-129 to iodine-131 for a 168-hour week as found in the 1959 ICRP report.

milk is not recommended because the methods for iodine determination, except for neutron activation, would probably give an error of around ±10 μg/liter for two standard deviations and the statistics using the ratio would be very poor. If the milk is consistently less than 10 μg/liter for iodine then the conventional method of dose determination assuming an uptake factor of 0.3 should be used.

In looking at iodine-131, the concept of determining dose from the ratio in milk must be approached with great caution because a lower biological half-life for iodine will require a proportionately higher amount of iodine in the diet, but will not lower the dose proportionately.

Burnett (*16*) has demonstrated that FRC calculations show 74 pCi/day corresponding to a dose to the infant thyroid of 500 mrem per year. The assumption of equilibrium can be made because "t" is much greater than T_e. The value of 74 can be computed from the previous equation as follows:

$$P = \frac{2.8 \times 10^3\, mR}{\xi f_w} \quad \frac{0.693}{T_e}$$

$$= \frac{(2.8 \times 10^3)(2)(9.61 \times 10^{-3})(0.693)}{(.22)\ (.3)\ (7.6)} \quad (5)$$

$$= 74\ \text{pCi/day}$$

The ratio of iodine-131 to iodine for 500 mrem per year infant thyroid dose for an intake of 1 liter per day comes out to be:

$$\frac{74\ \text{pCi/liter}}{11.7\ \mu g/\text{liter}} = 6.3\ \text{pCi}/\mu g \qquad (6)$$

If specific activity were to be used to calculate dose and there was 100 μg/liter of iodine-127, the amount of iodine-131 to give a dose of 500 mrem/year would be 630 pCi/liter instead of 80 pCi/liter.[2]

A more realistic approach to the use of the iodine-131 to iodine ratio would be to use a biological half-life of 20 days for the infant and still use a concentration of iodine in the thyroid of 350 $\mu g/g$ as follows:

Daily iodine requirement

$$I_d = \frac{(0.693)\ (2)\ (350)}{(0.3)\ (20)} = 81\ \mu g/\text{day} \qquad (7)$$

The corresponding allowable concentration of iodine-131 for a 20 day biological half-life to produce a thyroid dose of 500 mrem/year is 99 pCi/liter. The corresponding ratio is:

$$\text{Ratio} = \frac{99}{81} = 1.2\, \frac{^{131}I}{I}\ \text{in pCi}/\mu g \qquad (8)$$

The direct substitution in the formulas as was done for iodine-129 yields a relationship between dose and ratio as follows:

$$R = \frac{\xi C}{2.8 \times 10^3}\ \frac{T_e}{T_b}\ \frac{P_d}{I_d}\ \text{or}$$

$$D = 18.63\, \xi C\, \frac{T_e}{T_b}\ \frac{P_d}{I_d}\ \text{mrem/yr}$$

$$= (18.6)(.22)(350)\left(\frac{5.7}{20}\right)\ \frac{P_d}{I_d}$$

$$= 408\, \frac{^{131}I}{I}\ (\text{for } T_b = 20\ \text{d}, \ \&\ C = 350\ \mu g/g) \qquad (9)$$

Table 3 gives an allowable concentration of iodine-131 to produce a 5 mrem/year dose to the thyroid of the 1-year-old child based on the iodine concentration and compares this to the recommendation of FRC.

For iodine-131, it is suggested that the ratio of iodine-131 to iodine be used to predict yearly man-rem dose to the thyroids of infants when the concentration of iodine in the milk samples

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[2] FRC rounded off 74 to 80 and for action guides rounded it off to 100 (see Burnett (*16*)).

Table 3. Allowable concentration of iodine-131 versus concentration of iodine

(For 5 mrem/yr to infant thyroid and C = 350 μg/g)

Actual iodine (μg/liter)	Allowable iodine-131 [a] (pCi/liter)	Recommendation of FRC [b] iodine-131 (pCi/liter)
70	0.8	0.8
100	1.2	.8
200	2.4	.8
500	6.0	.8

[a] $T_b = 20$ d; $m = 2$ g; $\xi = 0.22$ MeV.
[b] $T_b = 138$ d; $m = 2$ g; $\xi = 0.22$ MeV.

consistently exceeds 70 μg/liter, and, below this value, use the present method of dose assessment. Since iodine-127 in cow's milk decreases when the cows return to pasture and may consistently be less than 70 μg/liter, there will not be as much use of the ratio for iodine-131 dose determination as for iodine-129.

Conclusions and recommendations

In order to use specific activity of iodine isotopes in milk to calculate thyroid doses to members of the general public, it will be necessary to establish a range of iodine concentrations in the thyroid based on age groups or a relationship between iodine intake and iodine thyroid concentration which may also be a function of age.

Specific activity for radioiodines in milk should not be used for design or control of nuclear facilities. The degree of radioiodine removal should not be dependent on differences in dairy farming practices. Use of compounds such as EDDI could drastically change iodine concentrations in milk.

A study of stable iodine concentrations in milk in various parts of the country and in different seasons is recommended to determine the ranges of stable iodine and possible reasons for fluctuations. This will be important in determining aggregate man-rem thyroid doses.

In calculating actual yearly man-rem thyroid doses to the general public from drinking of milk, more realistic doses can be determined from specific activity when there is an excess of iodine in the milk. If a concentration of 350 μg of iodine per gram of thyroid tissue is used, then the dose can be determined as follows:

Use 440 times the ratio of iodine-129 to iodine in pCi/μg to calculate yearly mrem thyroid dose when iodine in milk consistently exceeds 10 μg/liter.

Use 410 times the ratio of iodine-131 to iodine in pCi/μg to calculate yearly thyroid dose to an infant when iodine in milk consistently exceeds 70 μg/liter. This is based on a 20 day biological half-life.

If the concentration of iodine in the thyroid "C" is equal to 1000 μg/g, then the above doses should be multiplied by a factor of 2.9.

Specific activity should not be used to determine the dose from a short term ingestion of iodine-131 such as might occur in an emergency situation unless there is a good history of iodine levels in the local milk supplies to support use of specific activity. The feeding of increased amounts of iodine compounds normally being fed to cows to decrease dose to the thyroid is a possible emergency countermeasure that should be investigated further.

Acknowledgments

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Data

SECTION I. MILK AND FOOD

Milk Surveillance, April 1974

Although milk is only one of the sources of dietary intake of environmental radioactivity, it is the food item that is most useful as an indicator of the general population's intake of radionuclide contaminants resulting from environmental releases. Fresh milk is consumed by a large segment of the population and contains several of the biologically important radionuclides that may be released to the environment from nuclear activities. In addition, milk is produced and consumed on a regular basis, is convenient to handle and analyze, and samples representative of general population consumption readily can be obtained. Therefore, milk sampling networks have been found to be an effective mechanism for obtaining information on current radionuclide concentrations and long-term trends. From such information, public health agencies can determine the need for further investigation or corrective public health action.

The Pasteurized Milk Network (PMN) sponsored by the Office of Radiation Programs, Environmental Protection Agency, and the Office of Food Sanitation, Food and Drug Administration, Public Health Service, consists of 65 sampling stations: 63 located in the United States, one in Puerto Rico, and one in the Canal Zone. Many of the State health departments also conduct local milk surveillance programs which provide more comprehensive coverage within the individual State. Data from 15 of these State networks are reported routinely in *Radiation Data and Reports*. Additional networks for the routine surveillance of radioactivity in milk in the Western Hemisphere and their sponsoring organizations are:

Pan American Milk Sampling Program (Pan American Health Organization and U.S. Environmental Protection Agency)—5 sampling stations.

Canadian Milk Network (Radiation Protection Division, Canadian Department of National Health and Welfare)—16 sampling tions.

The sampling locations that make up the networks reporting presently in *Radiation Data and Reports* are shown in figure 1. Based on the similar purpose for these sampling activities, the present format integrates the complementary data that are routinely obtained by these several milk networks.

Radionuclide and element coverage

Considerable experience has established that relatively few of the many radionuclides that are formed as a result of nuclear fission become incorporated in milk (*1*). Most of the possible radiocontaminants are eliminated by the selective metabolism of the cow, which restricts gastrointestinal uptake and secretion into the milk. The five fission product radionuclides which commonly occur in milk are strontium-89, strontium-90, iodine-131, cesium-137, and barium-140. A sixth radionuclide, potassium-40, occurs naturally in 0.0118 percent (*2*) abundance of the element potassium, resulting in a specific activity for potassium-40 of 830 pCi/g total potassium.

Two stable elements which are found in milk, calcium and potassium, have been used as a means for assessing the biological behavior of

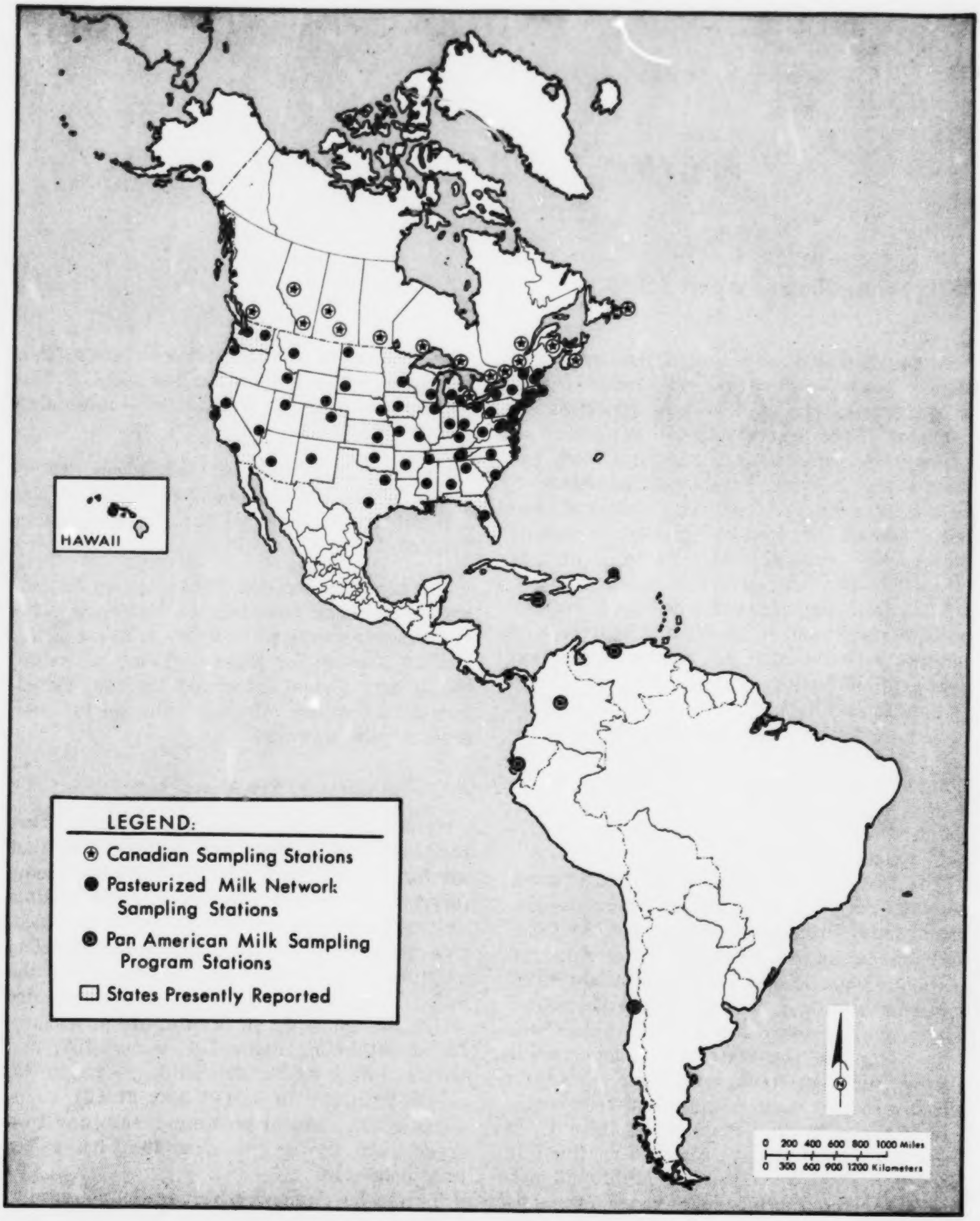
HAWAII
LEGEND:
Canadian Sampling Stations
Pasteurized Milk Network Sampling Stations
Pan American Milk Sampling Program Stations
States Presently Reported
N
0 200 400 600 800 1000 Miles
0 300 600 900 1200 Kilometers

Figure 1. Milk sampling networks in the Western Hemisphere

metabolically similar radionuclides (radiostrontium and radiocesium, respectively). The contents of both calcium and potassium in milk have been measured extensively and are relatively constant. Appropriate values and their variations, expressed in terms of 2 standard deviations (2σ), for these elements are 1.16 ± 0.08 g/liter for calcium and 1.51 ± 0.21 g/liter for potassium. These figures are averages of data from the PMN for May 1963–March 1966 (*3*) and are used for general radiation calculations.

Accuracy of data from various milk networks

In order to combine data from the international, national, and State networks considered in this report, first it was necessary to determine the accuracy with which each laboratory is making its determinations and the agreement of the measurements among the laboratories. The Analytical Quality Control Service of the Research and Development Programs conducts periodic studies to assess the accuracy of determinations of radionuclides in milk performed by interested radiochemical laboratories. The generalized procedure for making such a study has been previously outlined (*4*).

The most recent study was conducted during June 1972 with 37 laboratories participating in an experiment on a milk sample containing known concentrations of iodine-131, cesium-137, strontium-89, and strontium-90 (*5*). Of the 18 laboratories producing data for the network reports in *Radiation Data and Reports*, 14 participated in the study.

The accuracy results of this study for these 14 laboratories are shown in table 1. The accuracy of the cesium-137 measurements continues to be excellent as in previous experiments. However, both the accuracy and precision need to be improved for iodine-131, strontium-89, and strontium-90 which could probably be accomplished through recalibration.

Development of a common reporting basis

Since the various networks collect and analyze samples differently, a complete understanding of several parameters is useful for interpreting the data. Therefore, the various milk surveillance networks that report regularly were surveyed for information on analytical methods, sampling and analysis frequencies, and estimated analytical errors associated with the data.

In general, radiostrontium is collected by an ion-exchange technique and determined by beta-particle counting in low-background detectors, and the gamma-ray emitters (potassium-40, iodine-131, cesium-137, and barium-140) are determined by gamma-ray spectroscopy of whole milk. Each laboratory has its own modifications and refinements of these basic methodologies.

Many networks collect and analyze samples on a monthly basis. Some collect samples more frequently but composite the several samples for one analysis, while others carry out their analyses more often than once a month. Many networks are analyzing composite samples on a quarterly basis for certain nuclides. The fre-

Table 1. Distribution of mean results, quality control experiment

Isotope and known concentration		Number of laboratories in each category				Experimental 2σ error (pCi/liter)
		Acceptable [a]	Warning level [b]	Unacceptable [c]	Total	
Iodine-131:	(96 or 99 pCi/liter)	7 (58%)	1 (8%)	4 (33%)	12	6
	(438 or 484 pCi/liter)	11 (85%)	0	2 (15%)	13	25 or 28
Cesium-137:	(53 or 54 pCi/liter)	11 (92%)	0	1 (8%)	12	6
	(295 or 303 pCi/liter)	11 (85%)	2 (15%)	0	13	17
Strontium-89:	(29 or 30 pCi/liter)	9 (82%)	0	2 (18%)	11	6
	(197 or 201 pCi/liter)	3 (33%)	1 (11%)	5 (56%)	9	11 or 12
Strontium-90:	(32.1 or 32.4 pCi/liter)	4 (33%)	4 (33%)	4 (33%)	12	1.9
	(150.5 or 151.2 pCi/liter)	6 (55%)	0	5 (45%)	11	8.7

[a] Measured concentration equal to or within 2σ of the known concentration.
[b] Measured concentration outside 2σ and equal to or within 3σ of the known concentration.
[c] Measured concentration outside 3σ of the known concentration.

quency of collection and analysis varies not only among the networks but also at different stations within some of the networks. In addition, the frequency of collection and analysis is a function of current environmental levels. The number of samples analyzed at a particular sampling station under current conditions is reflected in the data presentation. Current levels for strontium-90 and cesium-137 are relatively stable over short periods of time, and sampling frequency is not critical. For the short-lived radionuclides, particularly iodine-131, the frequency of analysis is critical and generally is increased at the first measurement or recognition of a new influx of this radionuclide.

The data in table 2 show whether raw or pasteurized milk was collected. An analysis (*6*) of raw and pasteurized milk samples collected during January 1964 to June 1966 indicated that for relatively similar milkshed or sampling areas, the differences in concentration of radionuclides in raw and pasteurized milk are not statistically significant (*6*). Particular attention was paid to strontium-90 and cesium-137 in that analysis.

Practical reporting levels were developed by the participating networks, most often based on 2-standard-deviation counting errors or 2-standard-deviation total analytical errors from replicate analyses (*3*). The practical reporting level reflects analytical factors other than statistical radioactivity counting variations and will be used as a practical basis for reporting data.

The following practical reporting levels have been selected for use by all networks whose practical reporting levels were given as equal to or less than the given value.

Radionuclide	Practical reporting level (pCi/liter)
Strontium-89	5
Strontium-90	2
Iodine-131	10
Cesium-137	10
Barium-140	10

Some of the networks gave practical reporting levels greater than those above. In these cases, the larger value is used so that only data considered by the network as meaningful will be presented. The practical reporting levels apply to the handling of individual sample determinations. The treatment of measurements equal to or below those practical reporting levels for calculation purposes, particularly in calculating monthly averages, is discussed in the data presentation.

Analytical error of precision expressed as pCi/liter or percent in a given concentration range also has been reported by the networks (*3*). The precision errors reported for each of the radionuclides fall in the following ranges:

Radionuclide	Analytical errors of precision (2 standard deviations)
Strontium-89	1–5 pCi/liter for levels <50 pCi/liter; 5–10% for levels ≥50 pCi/liter;
Strontium-90	1–2 pCi/liter for levels <20 pCi/liter; 4–10% for levels ≥20 pCi/liter;
Iodine-131 Cesium-137 Barium-140	4–10 pCi/liter for levels <100 pCi/liter; 4–10% for levels ≥100 pCi/liter.

For iodine-131, cesium-137, and barium-140, there is one exception for these precision error ranges: 25 pCi/liter at levels <100 pCi/liter for Colorado. This is reflected in the practical reporting level for the Colorado milk network.

Federal Radiation Council guidance applicable to milk surveillance

In order to place the United States data on radioactivity in milk in perspective, a summary of the guidance provided by the Federal Radiation Council for specific environmental conditions was presented in the February 1973 issue of *Radiation Data and Reports.*

Data reporting format

Table 2 presents the integrated results of the international, national, and State networks discussed earlier. Column 1 lists all the stations which are reported routinely in *Radiation Data and Reports*. The relationship between the PMN

Table 2. Concentrations of radionuclides in milk for April 1974 and 12-month period, May 1973 through April 1974

Sampling location		Type of sample [a]	Radionuclide concentration (pCi/liter)			
			Strontium-90		Cesium-137	
			Monthly average [b]	12-month average	Monthly average [b]	12-month average
UNITED STATES:						
Ala:	Montgomery [c]	P	NA	3	12	3
Alaska:	Palmer [c]	P	NA	4	13	2
Ariz:	Phoenix [c]	P	NA	0	0	0
Ark:	Little Rock [c]	P	NA	12	11	1
Calif:	Los Angeles [c]	P	NA	0	0	0
	Sacramento [c]	P	NA	0	0	1
	San Francisco [c]	P	NA	0	0	0
	Del Norte	P	NA		NA	
	Fresno	P	NA		NA	
	Humboldt	P	NA		NA	
	Los Angeles	P	NA		NA	
	Mendocino	P	NA		NA	
	Sacramento	P	NA		NA	
	San Diego	P	NA		NA	
	Santa Clara	P	NA		NA	
	Shasta	P	NA		NA	
	Sonoma	P	NA		NA	
Colo:	Denver [c]	P	NA	3	0	0
	East	R	NA	NA	NS	23
	Northeast	R	NS	NA	NS	0
	Northwest	R	NS	NA	NS	4
	South Central	R	NS	NS	NS	NS
	Southeast	R	NS	NA	NS	0
	Southwest	R	NA	NA	0	0
	West	R	NS	NA	NS	0
Conn:	Hartford [c]	P	NA	4	0	2
	Central	P	NA		NA	
Del:	Wilmington [c]	P	NA	8	0	1
D.C:	Washington [c]	P	NA	4	0	0
Fla:	Tampa [c]	P	NA	4	32	25
	Central	R	5	5	15	28
	North	R	4	6	0	12
	Northeast	R	4	6	16	26
	Southeast	R	5	5	28	48
	Tampa Bay area	P	4	4	20	25
	West	R	7	8	16	10
Ga:	Atlanta [c]	P	NA	4	0	1
Hawaii:	Honolulu [c]	P	NA	0	0	0
Idaho:	Idaho Falls [c]	P	NA	4	0	0
Ill:	Chicago [c]	P	NA	5	0	0
Ind:	Indianapolis [c]	P	NA	5	0	3
	Central	P	5	5	0	4
	Northeast	P	6	5	0	10
	Northwest	P	5	7	0	7
	Southeast	P	6	6	0	6
	Southwest	P	7	7	0	5
Iowa:	Des Moines [c]	P	NA	4	0	0
	Des Moines	P	4	5	0 (4)	0
	Iowa City	P	5	5	0	0
	LeMars	P	4	4	0	0
	Little Cedar	P	8	6	0	0
Kans:	Wichita [c]	P	NA	6	0	1
	Coffeyville	P	6	6	0	7
	Dodge City	P	6	5	0	7
	Falls City, Nebr	R	NS	5	NS	8
	Hays	P	4	6	0	5
	Kansas City	P	6	4	0	5
	Topeka	P	4	6	0	6
	Wichita	P	4	6	0	7
Ky:	Louisville [c]	P	NA	5	0	1
La:	New Orleans [c]	P	NA	5	0	2
Maine:	Portland [c]	P	NA	8	12	12
Md:	Baltimore [c]	P	NA	8	0	2
Mass:	Boston [c]	P	NA	8	0	7
Mich:	Detroit [c]	P	NA	6	0	3
	Grand Rapids [c]	P	NA	7	0	1
	Bay City	P	8	11	0	2
	Charlevoix	P	9	9	0	2
	Detroit	P	19	9	0	0
	Grand Rapids	P	12	13	0	5
	Lansing	P	5	11	0	3
	Marquette	P	11	12	7	6
	Monroe	P	9	13	0	1
	South Haven	P	11	14	0	2
Minn:	Minneapolis [c]	P	NA	7	0	1
	Bemidji	P	NS	7	NS	0
	Duluth	P	12	17	12	16
	Fergus Falls	P	6	7	0	0
	Little Falls	P	12	16	0	0
	Mankato	P	5	5	0	0
	Marshall	P	NS	3	NS	0

See footnotes at end of table.

Table 2. Concentrations of radionuclides in milk for April 1974 and 12-month period, May 1973 through April 1974—continued

Sampling location		Type of sample [a]	Radionuclide concentration (pCi/liter)			
			Strontium-90		Cesium-137	
			Monthly average [b]	12-month average	Monthly average [b]	12-month average
Minn:	Minneapolis	P	8	9	0	0
	Rochester	P	6	6	0	0
Miss:	Jackson [c]	P	NA	8	0	4
Mo:	Kansas City [c]	P	NA	4	0	0
	St. Louis [c]	P	NA	8	0	1
Mont:	Helena [c]	P	NA	0	0	0
Nebr:	Omaha [c]	P	NA	0	0	0
Nev:	Las Vegas [c]	P	NA	8	0	0
N.H:	Manchester [c]	P	NA	9	0	5
N.J:	Trenton [c]	P	NA	4	0	1
N. Mex:	Albuquerque [c]	P	NA	0	0	0
N.Y:	Buffalo [c]	P	NA	5	0	1
	New York City [c]	P	NA	4	0	2
	Syracuse [c]	P	NA	6	0	1
	Albany	P	NA	4	0	0
	Buffalo	P	NA	4	0	0
	Massena	P	NA	7	11	10
	New York City	P	NA	7	0	0
	Syracuse	P	NS	4	NS	0
N.C:	Charlotte [c]	P	NA	9	0	4
N. Dak:	Minot [c]	P	NA	6	0	0
Ohio:	Cincinnati [c]	P	NA	6	0	3
	Cleveland [c]	P	NA	7	0	2
Okla:	Oklahoma City [c]	P	NA	2	0	0
Oreg:	Portland [c]	P	NA	5	0	1
	Baker	P	NA		NA	
	Coos Bay	P	NA		NA	
	Eugene	P	NA		NA	
	Medford	P	NA		NA	
	Portland composite	P	NA		NA	
	Portland local	P	NA		NA	
	Redmond	P	NA		NA	
	Tillamook	P	NA		NA	
Pa:	Philadelphia [c]	P	NA	5	11	2
	Pittsburgh [c]	P	NA	10	0	2
	Dauphin	P	6	5	0	0
	Erie	P	7	7	0	0
	Philadelphia	P	6	5	0	0
	Pittsburgh	P	6	5	0	0
R.I:	Providence [c]	P	NA	4	14	4
S.C:	Charleston [c]	P	NA	5	13	8
	Anderson-01	R	NS	7	NS	0
	Anderson-02	R	NS	5	NS	0
	Chapin	R	7	7	8	7
	Clemson	R	NS	8	NS	8
	Columbia	R	7	7	16	10
	Fairfield	R	6	6	6	10
	Hartsville-02	R	NS	6	NS	9
	Hartsville-03	R	NS	13	NS	13
	Lee County	R	NS	7	NS	8
	Oconee County	R	NS	7	NS	5
	Pickens	R	NS	7	NS	9
	Williston	R	NS	7	NS	15
	Winnsboro	R	6	6	22	16
	York-01	R	NS	7	NS	6
	York-02	R	NS	5	NS	0
S. Dak:	Rapid City [c]	P	NA	8	0	1
Tenn:	Chattanooga [c]	P	NA	6	15	2
	Knoxville [c]	P	NA	0	15	2
	Memphis [c]	P	NA	6	0	2
	Chattanooga	P	NA	7	0	5
	Clinton	R	NA	7	0	5
	Fayetteville	R	NA	8	0	4
	Kingston	R	NA	8	0	3
	Knoxville	P	NA	6	0	4
	Lawrenceburg	R	NA	6	0	0
	Nashville	P	NA	5	0	4
	Pulaski	R	NA	6	0	3
	Sequoyah	R	NS	9	NS	6
Tex:	Austin [c]	P	NA	0	0	0
	Dallas [c]	P	NA	3	0	0
Utah:	Salt Lake City [c]	P	NA	2	0	0
Vt:	Burlington [c]	P	NA	5	0	4
Va:	Norfolk [c]	P	NA	6	0	1
Wash:	Seattle [c]	P	NA	0	0	0
	Spokane [c]	P	NA	4	0	0
	Benton County	R	NS	0	NS	0
	Franklin County	R	3	1	0	6
	Longview	R	8	5	0	7
	Sandpoint, Idaho	R	4	5	0	1
	Skagit County	R	1	4	0	0
W. Va:	Charleston [c]	P	NA	8	0	2
Wisc:	Milwaukee [c]	P	NA	3	0	1
Wyo:	Laramie [c]	P	NA	0	0	1

See footnotes at end of table.

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Table 2. Concentrations of radionuclides in milk for April 1974 and 12-month period, May 1973 through April 1974—continued

Sampling location		Type of sample [a]	Radionuclide concentration (pCi/liter)			
			Strontium-90		Cesium-137	
			Monthly average [b]	12-month average	Monthly average [b]	12-month average
CANADA:						
Alberta:	Calgary	P	NA		2	6
	Edmonton	P	NA		6	9
British Columbia:	Vancouver	P	NA		4	11
Manitoba:	Winnipeg	P	NA		7	9
New Brunswick:	Moncton	P	NA		4	9
Newfoundland:	St. John's	P	NA		8	13
Nova Scotia:	Halifax	P	NA		2	8
Ontario:	Ottawa	P	NA		3	6
	Sault Ste. Marie	P	NA		4	13
	Thunder Bay	P	NA		13	9
	Toronto	P	NA		2	5
	Windsor	P	NA		5	5
Quebec:	Montreal	P	NA		4	5
	Quebec	P	NA		3	11
Saskatchewan:	Regina	P	NA		1	5
	Saskatoon	P	NA		2	6
CENTRAL AND SOUTH AMERICA:						
Canal Zone:	Cristobal [c]	P	NS	0	NS	0
Chile:	Santiago	P	0	0	11	1
Colombia:	Bogota	P	0	1	0	0
Ecuador:	Guayaquil	P	0	1	0	0
Jamaica:	Kingston	P	NS	4	NS	24
Puerto Rico:	San Juan [c]	P	NA	3	0	2
Venezuela:	Caracas	P	0	0	0	1
PMN network average [d]			5	5	2	2

[a] P, pasteurized milk,
R, raw milk.

[b] When an individual sampling result was equal to or less than the practical reporting level, a value of "0" was used for averaging. Monthly averages less than the practical reporting level reflect the fact that some but not all of the individual samples making up the average contained levels greater than the practical reporting level. When more than one analysis was made in a monthly period, the number of samples in the monthly average is given in parentheses.

[c] Pasteurized Milk Network station. All other sampling locations are part of the State or National network.

[d] This entry gives the average radionuclide concentrations for the Pasteurized Milk Network stations denoted by footnote [c].
NA, no analysis.
NS, no sample collected.

stations and the State stations is shown in figure 2. The first column in table 2 under each of the reported radionuclides gives the monthly average for the station and the number of samples analyzed in that month in parentheses. When an individual sampling result is equal to or below the practical reporting level for the radionuclide, a value of zero is used for averaging. Monthly averages are calculated using the above convention. Averages which are equal to or less than the practical reporting levels reflect the presence of radioactivity in some of the individual samples greater than the practical reporting level.

The second column under each of the radionuclides reported gives the 12-month average for the station as calculated from the preceding 12 monthly averages, giving each monthly average equal weight. Since the daily intake of radioactivity by exposed population groups, averaged over a year, constitutes an appropriate criterion for the case where the FRC radiation protection guides apply, the 12-month average serves as a basis for comparison.

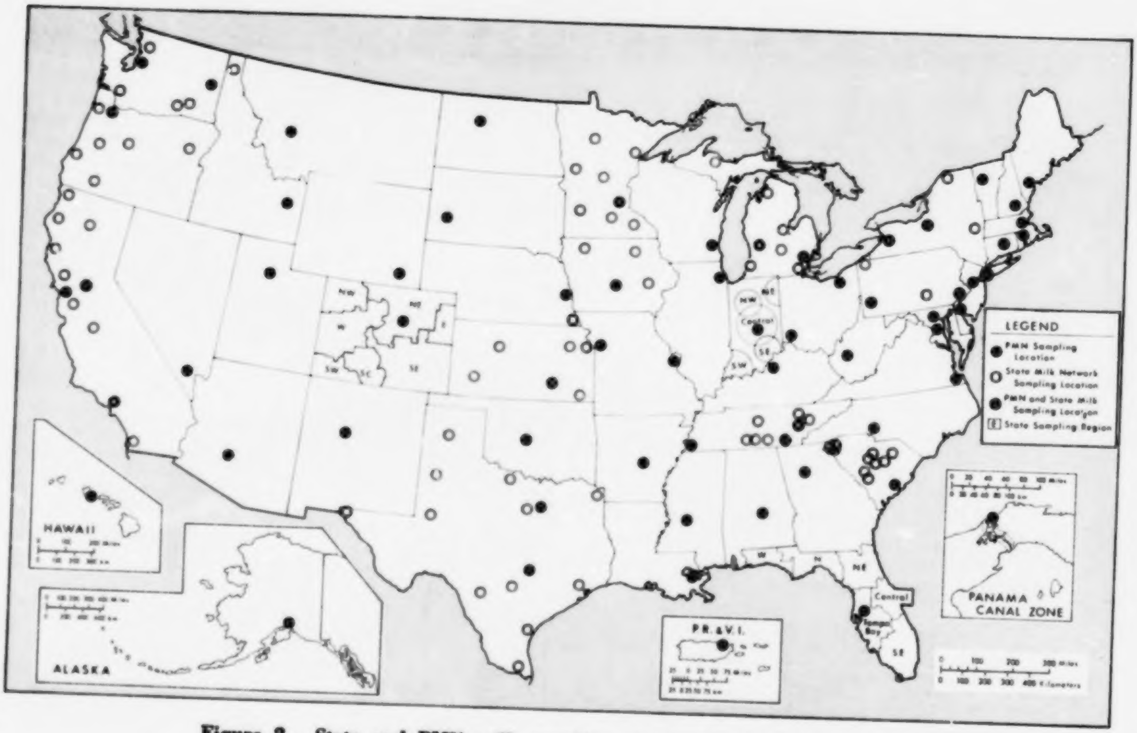

Figure 2. State and PMN milk sampling stations in the United States

Discussion of current data

In table 2, surveillance results are given for strontium-90 and cesium-137 for April 1974 and the 12-month period, May 1973 to April 1974. Except where noted, the monthly average represents a single sample for the sampling station. Strontium-89, iodine-131, and barium-140 data have been omitted from table 2 since levels at all of the stations for April 1974 were below the respective practical reporting levels. The following station average reflects a sample in which barium-140 was detected: Kans: Hays (State), 10 pCi/liter.

Strontium-90 monthly averages ranged from 0 to 19 pCi/liter in the United States for April 1974 and the highest 12-month average was 17 pCi/liter (Duluth, Minn.) representing 8.5 percent of the Federal Radiation Council radiation protection guide. Cesium-137 monthly averages ranged from 0 to 32 pCi/liter in the United States for April 1974, and the highest 12-month average was 48 pCi/liter (Southeast Florida) representing 1.3 percent of the value derived from the recommendations given in the Federal Radiation Council report. Table 3 gives the

Table 3. Strontium-89 and strontium-90 results of PMN milk samples composited by region

EPA region	States located in region	Strontium-90[a] concentration (pCi/liter)
I	Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, Vermont	5
II	New Jersey, New York, Puerto Rico	4
III	Delaware, District of Columbia, Maryland, Pennsylvania, Virginia, West Virginia	6
IV	Alabama, Canal Zone, Florida, Georgia, Kentucky, Mississippi, North Carolina, South Carolina, Tennessee	7
V	Illinois, Indiana, Michigan, Minnesota, Ohio, Wisconsin	6
VI	Arkansas, Louisiana, New Mexico, Oklahoma, Texas	6
VII	Iowa, Kansas, Missouri, Nebraska	6
VIII	Colorado, Montana, North Dakota, South Dakota, Utah, Wyoming	4
IX	Arizona, California, Hawaii, Nevada	0
X	Alaska, Idaho, Oregon, Washington	4

[a] All strontium-89 results were less than the practical reporting level (5 pCi/liter).

strontium-89 and strontium-90 results of PMN milk samples composited by region.

The Office of Radiation Programs is in the process of modifying the milk program to make it more responsive to potential sources of environmental radioactivity. These changes will be reflected in future articles.

Acknowledgement

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Radiologic Health Section
Environmental Control Component
California Department of Health

Radiation Protection Bureau
Canadian Department of National
Health and Welfare

Radiological Health Section
Division of Occupational and
Radiological Health
Colorado Department of Health

Laboratory Division
Connecticut Department of Health

Radiological and Occupational Health Section
Department of Health and Rehabilitative
Services
State of Florida

Bureau of Environmental Sanitation
Division of Sanitary Engineering
Indiana State Board of Health

Division of Radiological Health
Environmental Engineering Services
Iowa State Department of Health

Radiation Control Section
Environmental Health Division
Kansas State Department of Health

Radiological Health Services
Division of Occupational Health
Michigan Department of Health

Radiation Control Section
Division of Environmental Health
State of Minnesota Department of Health

Bureau of Radiological Pollution Control
New York State Department of
Environmental Conservation

Environmental Radiation Surveillance
Program
Division of Sanitation and Engineering
Oregon State Board of Health

Radiological Health Section
Bureau of Environmental Health
Pennsylvania Department of Public Health

Division of Radiological Health
South Carolina Department of Health
and Environmental Control

Radiological Health Services
Division of Preventable Diseases
Tennessee Department of Public Health

Radiation Control Section
Division of Health
Washington Department of Social
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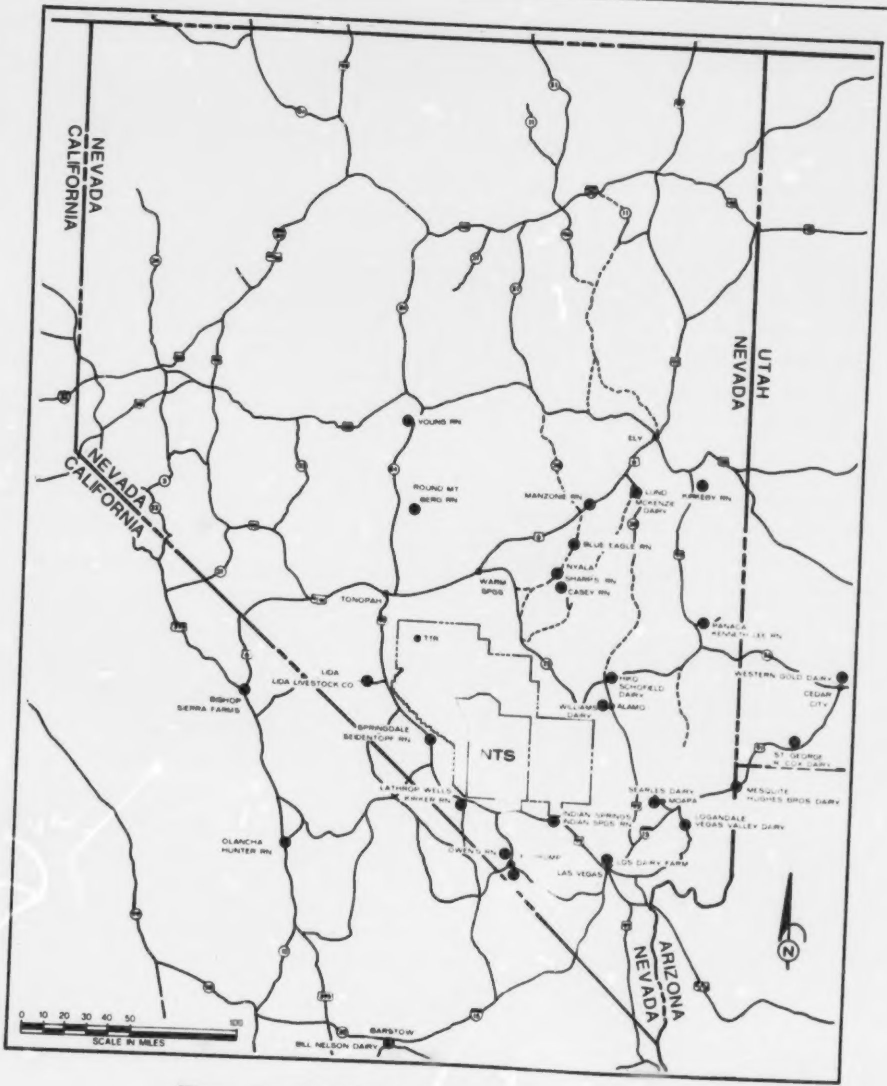
NEVADA
CALIFORNIA
NEVADA
CALIFORNIA
UTAH
NEVADA
YOUNG RN
ROUND MT
BERG RN
ELY
MANZONE RN
LUND
MCKENZIE DAIRY
KIRKEBY RN
BLUE EAGLE RN
NYALA
SHARPS RN
CASEY RN
WARM SPGS
TONOPAH
PANACA
KENNETH LEE RN
TTR
LIDA
LIDA LIVESTOCK CO
BISHOP
SERRA FARMS
HRD SCHOFIELD DAIRY
WILLIAMS DAIRY
ALAMO
WESTERN GOLD DAIRY
CEDAR CITY
SPRINGDALE
SEIDENTOPF RN
NTS
ST GEORGE
N COX DAIRY
LATHROP WELLS
KIRKER RN
SEARLES DAIRY
MOAPA
MESQUITE
HUGHES BROS DAIRY
INDIAN SPRINGS
INDIAN SPGS RN
LOGANDALE
VEGAS VALLEY DAIRY
OLANCHA
HUNTER RN
OWENS RN
PAHRUMP
LOS DAIRY FARM
LAS VEGAS
ARIZONA
NEVADA
N
0 10 20 30 40 50 100
SCALE IN MILES
BARSTOW
BILL NELSON DAIRY

Figure 1. NERC-LV Milk Surveillance Network

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Milk Surveillance Network, Second Quarter 1974

National Environmental Research Center—
Las Vegas
Environmental Protection Agency

The Milk Surveillance Network,[1] operated by the National Environmental Research Center—Las Vegas (NERC-LV) consists of 24 routine and 1 alternate sampling location (figure 1) situated in the offsite area surrounding the Nevada Test Site (NTS). This routine network is operated in support of the nuclear testing sponsored by the U.S. Atomic Energy Commission (AEC) at the Nevada Test Site (NTS).

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[1] The Milk Surveillance Network is operated under a Memorandum of Understanding (No. AT(26–1)–539) with the Nevada Operations Office, U.S. AEC, Las Vegas, Nev.

Table 1. Milk surveillance results, April-June 1974

Location	Date collected (1974)	Sample type [a]	Radionuclide concentrations [b] (pCi/liter)			
			Cesium-137	Strontium-89	Strontium-90	Tritium
California:						
Bishop:						
Sierra Creamery	4/ 3	11	<10	<1.5	2.2±0.87	NA
Hinkley:						
Bill Nelson Dairy	4/ 2	12	<10	<1.4	1.4±1.1	NA
Olancha:						
Hunter Ranch	4/ 2	13	<10	<1.3	<1.0	NA
Nevada:						
Alamo:						
Williams Dairy	4/ 9	12	<10	<1.6	1.9±1.2	NA
Austin:						
Young's Ranch	4/ 2	13	<10	<1.4	2.2±1.1	770±220
Currant:						
Blue Eagle Ranch	4/ 9	13	<10	<1.4	1.0± .85	NA
Manzonie Ranch	4/ 9	13	<10	<1.2	<1.0	NA
Hiko:						
Schofield Dairy	4/ 8	12	<10	<1.5	1.6±1.2	420±210
Indian Springs:						
Indian Springs Ranch	NS					
Las Vegas:						
LDS Dairy Farms	4/ 5	12	<10	<1.1	1.1± .89	350±220
Lathrop Wells:						
Kirker Ranch	4/11	13	<10	<1.3	1.5± .82	NA
Lida:						
Lida Livestock Company	4/ 1	13	<10	<1.6	<1.1	NA
Logandale:						
Vegas Valley Dairy	4/ 1	12	<10	<1.8	<1.2	NA
Lund:						
McKenzie Dairy	4/ 9	12	<10	<1.3	1.5±1.1	790±220
Mesquite:						
Hughes Bros. Dairy	4/ 1	12	<10	<1.3	2.6±1.1	240±220
Moapa:						
Searles Dairy	4/ 1	12	<10	<1.4	2.8±1.1	NA
Nyala:						
Sharp's Ranch	4/ 4	13	[c] <100	<1.6	2.9± .99	<210
Pahrump:						
Burson Ranch	4/12	13	<10	<1.3	1.5±1.0	NA
Panaca:						
Kenneth Lee Ranch	4/10	13	<10	<1.2	1.1± .96	NA
Round Mountain:						
Berg Ranch	4/ 2	13	<10	<1.8	4.5±1.4	NA
Shoshone:						
Kirkeby Ranch	4/ 8	13	<10	<2.0	<1.2	NA
Springdale:						
Seidentopf Ranch	4/10	13	<10	<1.6	1.3±1.2	NA
Utah:						
Cedar City:						
Western Gold Dairy	4/ 2	12	<10	<1.2	1.4± .98	NA
St. George:						
R. Cox Dairy	4/ 1	12	<10	<1.3	<.98	NA

[a] 11—Pasteurized milk.
12—Raw milk from Grade A producer(s).
13—Raw milk from family cow(s).
[b] Two-sigma counting error provided when available.
[c] Small sample size increased minimum detectable activity.
NA, no analysis.
NS, no sample.

In the event of a release of radioactivity from the NTS, special sampling within the affected area is conducted to determine radionuclide concentrations. Additional milk sampling networks are operated in support of AEC operations in areas other than the NTS when requested. A complete description of sampling and analytical procedures was included with the milk results reported in the July 1973 issue of *Radiation Data and Reports.*

Results

The analytical results of all milk samples collected in the second quarter of 1974 by NERC-LV are listed in table 1. With the exception of cesium-137 at levels near the minimum detectable concentration (MDC) of 10 pCi/liter, no gamma-emitting fission products were identified by gamma spectrometry in any of the samples collected in the second quarter. Levels of tritium near the MDC for this radionuclide (~200 pCi/liter) were also measured by liquid scintillation counting techniques. The highest concentration of tritium during the second quarter was 790 ± 220 pCi/liter. The levels of cesium-137 and tritium measured in the milk were attributed to worldwide fallout.

Food and Diet Surveillance

Efforts are being made by various Federal and State agencies to estimate the dietary intake of selected radionuclides on a continuing basis. These estimates, along with the guidance developed by the Federal Radiation Council, provide a basis for evaluating the significance of radioactivity in foods and diet.

Networks presently in operation and reported routinely include those listed below. These networks provide data useful for developing estimates of nationwide dietary intakes of radionuclides. Programs reported in *Radiation Data and Reports* are as follows:

Program	Period reported	Issue
California Diet	July 1971–December 1972	February 1974
Carbon-14 in Total Diet and Milk	1972–1973	November 1973
Strontium-90 in Tri-City Diets	1972	December 1973

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SECTION II. WATER

The Environmental Protection Agency and other Federal, State, and local agencies operate extensive water quality sampling and analysis programs for surface, ground, and treated water. Most of these programs include determinations of gross beta and gross alpha radioactivity and specific radionuclides.

Although the determination of the total radionuclide intake from all sources is of primary importance, a measure of the public health importance of radioactivity levels in water can be obtained by comparison of the observed values with the Public Health Service Drinking Water Standards (*1*). These standards, based on consideration of Federal Radiation Council (FRC) recommendations (*2–4*) set the limits for approval of a drinking water supply containing radium-226 and strontium-90 at 3 pCi/liter and 10 pCi/liter, respectively. Higher concentrations may be acceptable if the total intake of radioactivity from all sources remains within the guides recommended by FRC for control action. In the known absence[1] of strontium-90 and alpha-particle emitters, the limit is 1000 pCi/liter gross beta radioactivity, except when additional analysis indicates that concentrations of radionuclides are not likely to cause exposures greater than the limits indicated by the Radiation Protection Guides. Surveillance data from a number of Federal and State programs are published periodically to show current and long-range trends. Water sampling activities reported in *Radiation Data and Reports* are listed below.

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[1] Absence is taken to mean a negligibly small fraction of the specific limits of 3 pCi/liter and 10 pCi/liter for unidentified alpha-particle emitters and strontium-90, respectively.

Water sampling program	Period reported	Issue
California	1971 and 1972	November 1973
Colorado River Basin	1968	March 1972
Community Water Supply Study	1969	September 1972
ERAMS Surface Water and Drinking Water Components	January–March 1974	August 1974
Florida	1970	April 1974
Interstate Carrier Drinking Water	1971	May 1972
Kansas	1972	August 1974
Minnesota	July 1971–June 1972	March 1974
New York	January–December 1972	June 1974
North Carolina	1971	July 1974
Radiostrontium in Tap Water, HASL	January–December 1972	December 1973
Washington	July 1970–June 1971	August 1973

REFERENCES

(*1*) U.S. PUBLIC HEALTH SERVICE. Drinking water standards, revised 1962, PHS Publication No. 956. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (March 1963).

(*2*) FEDERAL RADIATION COUNCIL. Radiation Guidance Protection for Federal Agencies. Memorandum for the President, September 1961. Reprint from the Federal Register of September 26, 1961.

(*3*) FEDERAL RADIATION COUNCIL. Background material for the development of Radiation Protection Standards, Report No. 1. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (May 1960).

(*4*) FEDERAL RADIATION COUNCIL. Background material for the development of Radiation Protection Standards, Report No. 2. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (September 1961).

Water Surveillance Network, Second Quarter 1974

National Environmental Research Center—
Las Vegas
Environmental Protection Agency

The Water Surveillance Network,[1] operated by the National Environmental Research Center—Las Vegas (NERC-LV), consists of 59 sampling locations (figures 1 and 2) in the offsite area surrounding the Nevada Test Site (NTS). This routine network is operated in support of the nuclear testing conducted by the U.S. Atomic Energy Commission (AEC) at the Nevada Test Site.

In the event of a release of radioactivity from the NTS, special sampling within the affected

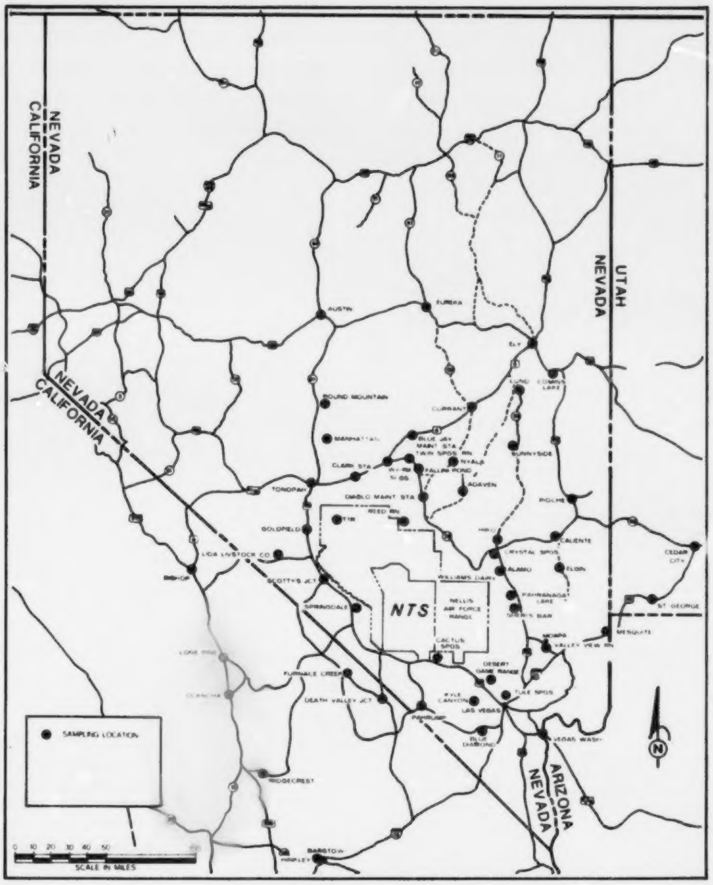
NEVADA
CALIFORNIA
UTAH
NEVADA
AUSTIN
EUREKA
ELY
LUND
COMINS LAKE
ROUND MOUNTAIN
CURRANT
MANHATTAN
BLUE JAY MAINT STA
TWIN SPGS RN
NYALA
CLARK STA
WARM SPGS
FALLINI POND
ADAVEN
SUNNYSIDE
TONOPAH
DIABLO MAINT STA
PIOCHE
REED RN
TTR
GOLDFIELD
HIKO
CALIENTE
CEDAR CITY
LIDA LIVSTOCK CO
CRYSTAL SPGS
ALAMO
ELGIN
BISHOP
SCOTTYS JCT
WILLIAMS DAIRY
NTS
NELLIS AIR FORCE RANGE
PAHRANAGAT LAKE
SPRINGDALE
SPARKS BAR
ST GEORGE
MESQUITE
CACTUS SPGS
MOAPA
VALLEY VIEW RN
LONE PINE
DESERT GAME RANGE
FURNACE CREEK
OLANCHA
KYLE CANYON
TULE SPGS
DEATH VALLEY JCT
LAS VEGAS
PAHRUMP
BLUE DIAMOND
VEGAS WASH
SAMPLING LOCATION
N
RIDGECREST
ARIZONA
NEVADA
0 10 20 30 40 50
SCALE IN MILES
BARSTOW
HINKLEY

Figure 1. NERC-LV Water Surveillance Network

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[1] The Water Surveillance Network is operated under a Memorandum of Understanding (No. AT(26–1)–539) with the Nevada Operations Office, U.S. AEC, Las Vegas, Nev.

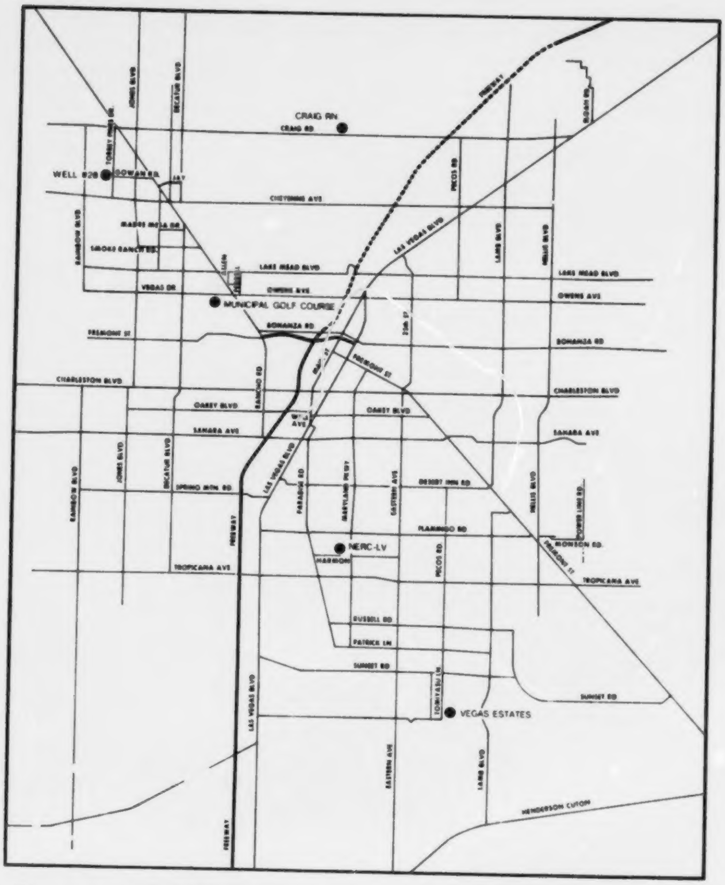
CRAIG RN
CRAIG RD
WELL #28
GOWAN RD
CHEYENNE AVE
LAKE MEAD BLVD
OWENS AVE
VEGAS DR
MUNICIPAL GOLF COURSE
BONANZA RD
FREMONT ST
CHARLESTON BLVD
OAKEY BLVD
SAHARA AVE
SPRING MTN RD
DESERT INN RD
FLAMINGO RD
NERC-LV
HARMON
TROPICANA AVE
RUSSELL RD
PATRICK LN
SUNSET RD
VEGAS ESTATES
HENDERSON CUTOFF
RAINBOW BLVD
JONES BLVD
DECATUR BLVD
FREEWAY
LAS VEGAS BLVD
PARADISE RD
MARYLAND PKWY
EASTERN AVE
PECOS RD
LAMB BLVD
NELLIS BLVD
BOULDER HWY

Figure 2. NERC-LV Water Surveillance Network—Las Vegas Valley

area is conducted to determine radionuclide concentrations. Additional water sampling networks are operated in support of AEC operations in areas other than the NTS when requested. A complete description of sampling and analytical procedures was included with the water results reported in the July 1973 issue of *Radiation Data and Reports*.

Results

The routine analytical results of all water samples collected in the second quarter of 1974 by the NERC-LV are listed in table 1. No gamma-emitting fission products were identified by gamma spectrometry in any of the second quarter samples.

Table 1. Water surveillance results, April-June 1974

Location	Date collected (1974)	Sample type [a]	Radionuclide concentrations [b] (pCi/liter)		
			Gross alpha	Gross beta	Tritium
California:					
Bishop:					
Fish and Game Office	4/ 3	23	<1.4	<3.2	NA
Death Valley Junction:					
Lila's Cafe	4/10	23	<4.2	10 ± 3.8	<210
Furnace Creek:					
Pond	4/ 4	21	6.4 ± 5.1	8.8 ± 3.7	NA
Visitor's Center	4/ 4	27	<3.7	12 ± 3.8	NA
Hinkley:					
Bill Nelson Dairy	4/ 2	23	7.8 ± 5.2	4.8 ± 3.4	NA
Lone Pine:					
Forest Service Ranger Station	4/ 2	24	<1.8	<3.2	NA
Olancha:					
Haiwee Reservoir	4/ 2	21	9.8 ± 4.7	5.9 ± 3.4	NA
Ridgecrest:					
City Hall	4/ 2	23	<3.0	<3.3	NA
Nevada:					
Adaven:					
Canfield Ranch	4/ 2	22	3.7 ± 2.9	<3.2	NA
Alamo:					
Pahranagat Lake	4/ 8	21	16 ± 7.1	18 ± 4.1	NA
Sheri's Bar	4/ 8	23	<2.9	4.0 ± 3.1	NA
Williams Dairy	4/ 8	23	<3.9	<3.1	NA
Austin:					
Nevada National Bank	4/ 3	27	21 ± 5.7	13 ± 3.8	NA
Blue Diamond:					
Post Office	4/ 9	23	<3.3	<3.1	<210
Blue Jay Highway Maintenance Station	4/11	23	<2.5	6.6 ± 3.3	NA
Cactus Springs:					
Mobil Service Station	4/12	27	<2.3	<3.1	<210
Caliente:					
Agricultural Extension Station	4/ 8	23	5.1 ± 3.4	4.9 ± 3.2	NA
Clark Station:					
Five Mile Ranch	4/11	27	<3.0	8.1 ± 3.4	NA
Currant:					
Currant Ranch Cafe	4/10	27	9.6 ± 5.2	5.3 ± 3.2	NA
Diablo:					
Highway Maintenance Station	4/ 2	23	4.7 ± 3.5	5.0 ± 3.3	NA
Reed Ranch	4/ 1	21	12 ± 5.6	18 ± 4.1	NA
Elgin:					
Water tower	4/10	23	11 ± 5.6	10 ± 3.7	NA
Ely:					
Chevron Service Station	NS				
Comins Lake	4/ 8	21	<2.8	15 ± 3.8	NA
Eureka:					
Highway Maintenance Station	4/10	24	<3.4	5.8 ± 3.2	NA
Goldfield:					
Chevron Service Station	4/ 4	23	<2.3	<3.2	NA
Hiko:					
Crystal Springs	4/ 8	27	<3.2	9.2 ± 3.4	NA
Schofield Dairy	4/ 8	23	24 ± 8.3	33 ± 4.8	NA
Las Vegas:					
Craig Ranch Golf Course	4/ 5	23	7.0 ± 3.8	6.6 ± 3.4	290 ± 220
Desert Game Range	4/12	23	<2.2	<3.1	<210
Lab I NERC	4/ 5	24	<3.0	<3.1	1 000 ± 230
Lake Mead Vegas Wash	4/ 5	21	7.0 ± 5.2	6.7 ± 3.5	940 ± 230
Las Vegas Water District Well 28	4/ 5	23	3.4 ± 2.7	<3.2	<210
Municipal Golf Course	4/ 5	23	<1.9	<3.2	<210
Tule Springs	4/15	23	6.6 ± 3.4	3.3 ± 3.1	<210
Tule Springs Pond	4/15	21	5.1 ± 3.2	3.4 ± 3.1	NA
Vegas Estates	4/05	23	7.9 ± 5.4	14 ± 4.0	<210
Lida:					
Lida Livestock Company	4/ 1	27	4.6 ± 3.6	<3.2	NA
Pond at storage tank	4/ 1	21	<2.8	<3.2	NA
Lund:					
Gardner Grocery	4/ 9	23	<2.9	4.0 ± 3.1	NA
Manhattan:					
Country store	4/ 3	23	9.8 ± 4.9	5.4 ± 3.4	NA
Mesquite:					
Hughes Bros. Dairy	4/ 1	23	6.2 ± 4.7	4.0 ± 3.3	NA
Moapa:					
Pedersen Valley View Ranch	4/ 1	27	<4.4	11 ± 3.8	NA
Mt. Charleston:					
Kyle Canyon Fire Station	4/12	27	<2.1	<3.1	330 ± 210
Nyala:					
Sharp's Ranch	4/ 4	23	3.5 ± 2.8	<3.2	NA
Pahrump:					
Texaco Service Station	4/ 9	23	3.5 ± 2.8	4.5 ± 3.2	NA
Pioche:					
County courthouse	4/10	24	<2.2	6.3 ± 3.3	NA
Round Mountain:					
Mobil Service Station	4/ 3	27	4.5 ± 3.0	<3.2	NA
Scotty's Junction:					
Holloway Ranch	4/ 1	23	6.3 ± 4.7	9.5 ± 3.7	<260
Springdale:					
Pond	4/10	21	<3.9	10 ± 3.7	NA

See footnotes at end of table.

Table. 1 Water surveillance results, April-June 1974—continued

Location	Date collected (1973)	Sample type [a]	Radionuclide concentrations [b] (pCi /liter)		
			Gross alpha	Gross beta	Tritium
Sunnyside:					
Adam McGill Reservoir	4/11	21	4.9± 4.2	12 ±3.7	NA
Wildlife Management Headquarters	4/11	27	4.8± 3.2	<3.0	NA
Tonopah:					
Jerry's Chevron Station	4/ 4	23	<2.7	4.7±3.3	NA
Tonopah Test Range CP-1	4/ 4	23	7.3± 4.4	4.8±3.3	NA
Warm Springs:					
Fallini's Pond	4/ 3	21	21 ± 9.1	49 ±5.8	NA
Service Station and Cafe	4/11	27	30 ±10	31 ±4.8	NA
Twin Springs Ranch	4/ 3	23	<3.2	10 ±3.7	NA
Utah:					
Cedar City:					
M. D. Baldwin residence	4/ 2	24	<1.3	<3.2	NA
St. George:					
R. Cox Dairy	4/ 1	24	3.4± 2.4	<3.2	NA

[a] 21—Pond, lake, reservoir, stock tank, stock pond.
22—Stream, river, creek.
23—Well.
24—Multiple supply mixed (a water sample consisting of mixed or multiple sources of water such as well and spring).
27—Spring.

[b] Two-sigma counting error provided when available.
NA, not analyzed.
NS, no sample.

SECTION III. AIR AND DEPOSITION

Radioactivity in Airborne Particulates and Precipitation

Continuous surveillance of radioactivity in air and precipitation provides one of the earliest indications of changes in environmental fission product radioactivity. To date, this surveillance has been confined chiefly to gross beta radioanalysis. Although such data are insufficient to assess total human radiation exposure from fallout, they can be used to determine when to modify monitoring in other phases of the environment.

Surveillance data from a number of programs are published monthly and summarized periodically to show current and long-range trends of atmospheric radioactivity in the Western Hemisphere. These include data from actvities of the Environmental Protection Agency, the Canadian Department of National Health and Welfare, and the Pan American Health Organization.

In addition to those programs presented in this issue, the following programs were covered previously in *Radiation Data and Reports*.

Network	Period	Issue
Fallout in the United States and Other Areas	1972	August 1974
Krypton-85 in air	July 1970–1972	March 1974
Mexican air monitoring program	July–December 1973	May 1974
Plutonium in airborne particulates	April–June 1973	June 1974

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1. ERAMS Gross Radioactivity and Deposition Component April 1974

Office of Radiation Programs
Environmental Protection Agency

The Environmental Radiation Ambient Monitoring System (ERAMS), which began in July 1973, was developed from previously operating radiation monitoring networks to form a single monitoring system which is more responsive to current and projected sources of environmental radiation.

The ERAMS Gross Radioactivity and Deposition Component is a restructuring of the previous Radiation Alert Network (RAN). Sampling stations were relocated (figure 1) to more closely monitor the potential sources of environmental radioactivity and to provide the means for obtaining the maximum population coverage. The component consists of 74 sampling stations, 55 of which are on standby status and can be activated when the need arises. The remaining 19 stations collect air particulates continuously with the filters being changed one or two times per week. Most of the stations are operated by State or local health department personnel.

The station operators perform gross beta radioactivity "field estimates" on the airborne particulate samples at 5 hours after collection, when most of the radon daughter products have decayed, and at 29 hours after collection, when most of the thoron daughter products have decayed. The airborne particulate samples and precipitation samples, which are collected concurrently with the 19 air sampling stations, are sent to the Eastern Environmental Radiation Facility for laboratory gross beta radioactivity analyses. All field estimate results are reported to the appropriate Environmental Protection Agency officials by mail or telephone depending on the levels found. A compilation of the daily

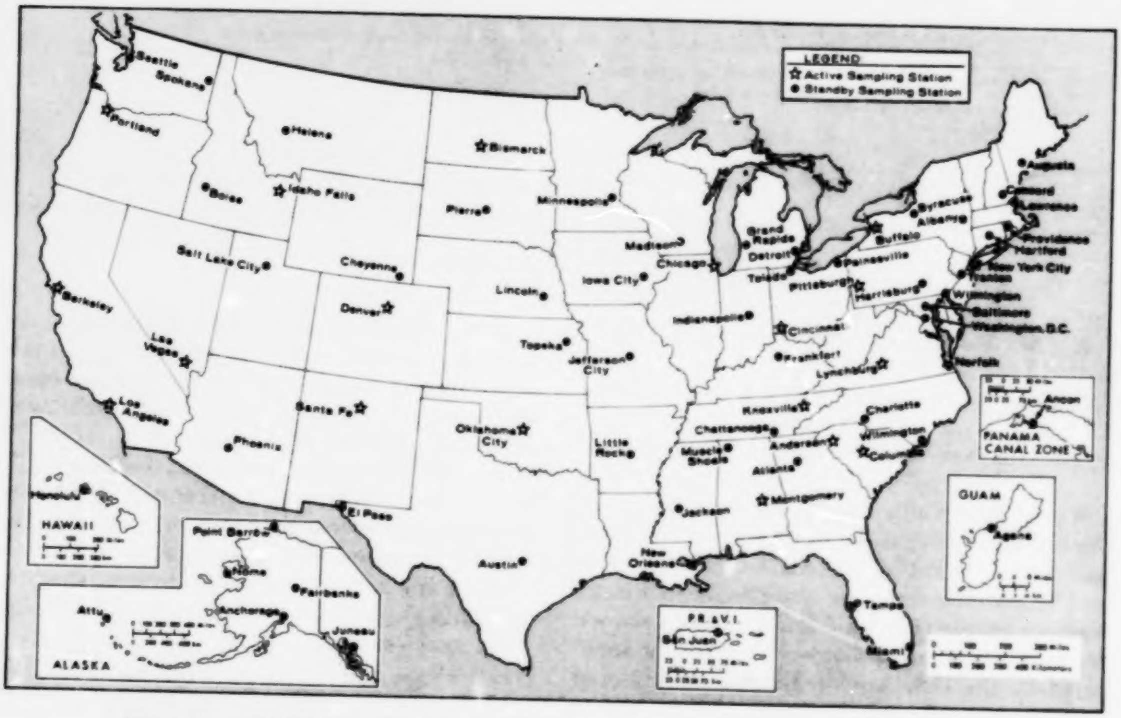
LEGEND
☆ Active Sampling Station
● Standby Sampling Station
Seattle
Spokane
Portland
Helena
Bismarck
Boise
Idaho Falls
Pierre
Minneapolis
Salt Lake City
Cheyenne
Berkeley
Denver
Lincoln
Las Vegas
Topeka
Jefferson City
Los Angeles
Santa Fe
Phoenix
Oklahoma City
Little Rock
El Paso
Austin
Madison
Chicago
Grand Rapids
Detroit
Toledo
Iowa City
Indianapolis
Cincinnati
Frankfort
Painesville
Pittsburgh
Harrisburg
Buffalo
Syracuse
Albany
Augusta
Concord
Lawrence
Providence
Hartford
New York City
Trenton
Wilmington
Baltimore
Washington, D.C.
Norfolk
Lynchburg
Knoxville
Chattanooga
Charlotte
Wilmington
Anderson
Columbia
Muscle Shoals
Atlanta
Montgomery
Jackson
New Orleans
Tampa
Miami
Ancon
PANAMA CANAL ZONE
GUAM
Agana
PR. & V.I.
San Juan
HAWAII
Honolulu
ALASKA
Point Barrow
Nome
Fairbanks
Anchorage
Juneau
Attu

Figure 1. ERAMS Gross Radioactivity and Deposition Component sampling locations

measurements is available upon request from the Eastern Environmental Radiation Facility, Montgomery, Ala. 36109.

Table 1 presents the monthly average gross beta radioactivity in surface air particulates and deposition by precipitation, as measured by the field estimate and laboratory techniques during April 1974.

Table 1. Gross beta radioactivity in surface air and precipitation, April 1974

Station location [a]		Number of samples	Gross beta radioactivity (pCi/m^3)						Precipitation	
			5-hour field estimate			Laboratory measurement			Laboratory estimate of deposition	
			Maximum	Minimum	Average[b]	Maximum	Minimum	Average[b]	Depth (mm)	Total deposition (nCi/m^2)
Ala:	Montgomery	9	1	0	1	0.47	0.10	0.24	79	1.08
Calif:	Berkeley	9	0	0	0	.26	.07	.11	27	.09
	Los Angeles	9	1	0	1	.31	.03	.17		
Colo:	Denver	9	2	1	1	.52	.11	.32	32	1.00
Idaho:	Idaho Falls	9				.39	.09	.20	22	.51
Ill:	Chicago	(c)								
Ind:	Indianapolis [d]	7	0	0	0	.24	.09	.17		
Nev:	Las Vegas	9	1	1	1	.38	.20	.29		
N. Mex:	Santa Fe	5	1	0	0	.42	.14	.30		
N.Y:	Buffalo	9	1	0	0	.33	.05	.15	13	.42
	New York City	(c)								
N. Dak:	Bismarck	8	2	0	1	.28	.07	.15	52	1.16
Ohio:	Columbus [e]	8	2	0	1	.35	<.01	.20		
Okla:	Oklahoma City	0								
Oreg:	Portland	22	1	0	0	.57	.03	.12		
Pa:	Harrisburg [f]	20	1	0	1	.28	.03	.14		
S.C:	Anderson	(c)								
	Columbia	8	1	0	0	.40	.06	.23	84	2.46
Tenn:	Knoxville	(c)								
Va:	Lynchburg	(c)								
Network summary		141	2	0	1	0.57	<0.01	0.20	44	0.96

[a] The remaining stations are on standby status.
[b] The monthly average is calculated by weighting the estimates of individual air samples with length of sampling period.
[c] Station to be established.
[d] Standby station operated continuously at the request of the State.
[e] Station to be relocated to Cincinnati.
[f] Station to be relocated to Pittsburgh.

2. Air Surveillance Network, April 1974

National Environmental Research Center—
Las Vegas
Environmental Protection Agency

The Air Surveillance Network,[1] operated by the National Environmental Research Center—Las Vegas (NERC-LV), consists of 49 active and 72 standby sampling stations located in 21 western States (figures 2 and 3). The network is operated in support of nuclear testing sponsored by the U.S. Atomic Energy Commission (AEC) at the Nevada Test Site (NTS), and at any other designated testing sites.

The stations are operated by State health department personnel and by private individuals on a contract basis. All active stations are operated continuously with filters being exchanged after periods generally ranging from 48 to 72 hours. All samples are mailed to the NERC-LV unless special retrieval is arranged at selected locations in response to known releases of radioactivity from the NTS. A complete description of sampling and analytical procedures was presented in the February 1972 issue of *Radiation Data and Reports*.

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[1] This network is operated under a Memorandum of Understanding (No. AT(26-1)-539) with the Nevada Operations Office, U.S. Atomic Energy Commission.

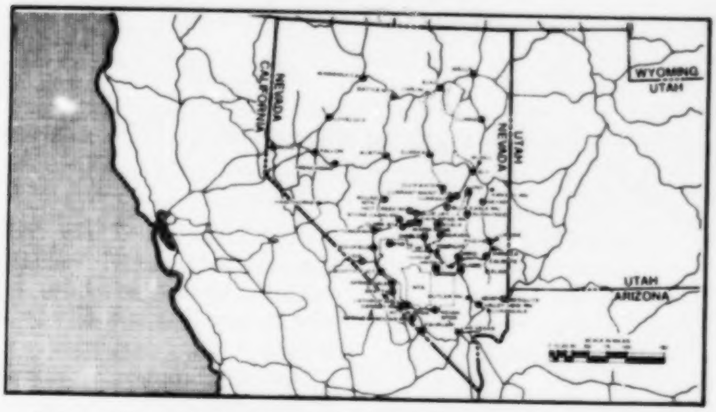
WYOMING
UTAH
NEVADA
CALIFORNIA
UTAH
NEVADA
UTAH
ARIZONA

Figure 2. NERC-LV Air Surveillance Network stations in Nevada

Table 2 presents the average gross beta concentrations in air for each of the active network stations and for all standby stations, which were activated on April 1 for 1 week of operation to check equipment and gather background information. The minimum reporting concentration for gross beta activity is 0.1 pCi/m^3. For reporting purposes, concentration less than 1.0 pCi/m^3 are reported to one significant figure, and those equal to or greater than 1.0 pCi/m^3 are reported to two significant figures. For averaging purposes, individual concentration values less than the minimum detectable concentration (~0.03 pCi/m^3 for a 700 m^3 sample) are set equal to the minimum detectable concentration (MDC). Reporting and rounding-off conventions are as follows:

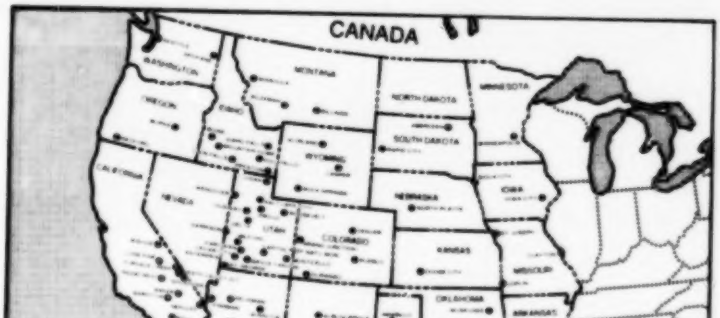
CANADA
WASHINGTON
MONTANA
NORTH DAKOTA
MINNESOTA
OREGON
IDAHO
SOUTH DAKOTA
WYOMING
CALIFORNIA
NEVADA
NEBRASKA
IOWA
UTAH
COLORADO
KANSAS
MISSOURI
OKLAHOMA
ARKANSAS
ARIZONA
NEW MEXICO
TEXAS
LOUISIANA
MEXICO
PREFILTER CHARCOAL CARTRIDGE GAMMA RATE RECORDER
PREFILTER GAMMA RATE RECORDER
PREFILTER CHARCOAL CARTRIDGE
PREFILTER ONLY
STANDBY STATIONS

Figure 3. NERC-LV Air Surveillance Network stations outside Nevada

Concentration (pCi/m^3)	Reported value of concentration above MDC (pCi/m^3)	Reported value of concentration below MDC (pCi/m^3)
<0.05	<0.1	<0.1
≥ 0.05 <0.15	0.1	<0.1
≥ 0.15	As calculated and rounded	<calculated MDC

As shown by table 2, the highest gross beta concentrations at continuously operated stations within the network were 1.8 pCi/m^3 at Milford, Utah, 1.3 pCi/m^3 at Blue Eagle Ranch, Nev., 1.2 pCi/m^3 at Kingman and Seligman, Ariz., and Nyala, Nev.

From gamma spectrometry results, fission products in varying combinations of zirconium-95, ruthenium-103, and cerium-141 were identified on filters collected throughout the network. The highest concentrations of these radionuclides, respectively, were 0.56 pCi/m^3 (Nyala), 0.14 pCi/m^3 (Shoshone), and 0.14 pCi/m^3 (Nyala). These radionuclides are attributed to seasonal variations in worldwide fallout. No radionuclides were identified by gamma spectrometry on any charcoal cartridges during April.

Complete copies of this summary and listings of the daily gross beta and gamma spectrometry results are distributed to EPA Regional Offices and appropriate State agencies. Additional copies of the daily results may be obtained from the NERC-LV upon written request.

Table 1. Summary of gross beta radioactivity concentration in air, April 1974

Location		Number of samples	Concentration (pCi/m^3)		
			Maximum	Minimum	Average
Ariz:	Kingman	13	1.2	<0.1	0.6
	Phoenix	2	.4	.3	.4
	Seligman	13	1.2	.2	.7
	Winslow	3	.6	.4	.5
Ark:	Little Rock	1	<.1	<.1	<.1
Calif:	Baker	13	.9	.3	.6
	Barstow	12	.7	<.1	.4
	Bishop	13	1.1	.2	.6
	Death Valley Junction	13	.9	.2	.6
	Furnace Creek	13	1.0	.4	.6
	Indio	3	.5	.2	.4
	Lone Pine	8	.8	.4	.5
	Needles	2	1.2	.8	.9
	Ridgecrest	13	.7	.3	.5
	Shoshone	13	1.1	.3	.6
Colo:	Denver	3	.4	.2	.3
	Durango	3	.3	<.1	.2
Idaho:	Boise	2	.2	.1	.1
	Idaho Falls	3	.3	.2	.3
	Preston	3	.4	.1	.2
	Twin Falls	3	.3	<.1	.2
Iowa:	Iowa City	3	.2	.1	.2
	Sioux City	3	.4	.2	.3
Kans:	Dodge City	3	.3	.1	.2
La:	Lake Charles	3	.4	.3	.3
	Monroe	3	.4	<.1	.2
	New Orleans	3	.3	.2	.3
Minn:	Minneapolis	3	.3	<.1	.2
Mo:	Clayton	3	.2	.2	.2
	Joplin	3	.3	.2	.2
	St. Joseph	2	.3	.3	.3
Nebr:	North Platte	3	.2	.2	.2
Nev:	Alamo	13	1.0	.4	.6
	Austin	13	.7	.2	.3
	Battle Mountain	3	.3	.2	.3
	Beatty	13	1.0	<.1	.5
	Blue Eagle Ranch (Currant)	13	1.3	.2	.5
	Blue Jay	13	.9	<.1	.5
	Caliente	13	.7	<.1	.5
	Currant Ranch	2	.4	.3	.3
	Currie	3	.4	.2	.3
	Diablo	13	1.0	<.1	.5
	Duckwater	13	.8	<.1	.3
	Elko	3	.4	<.1	.3

Table 1. Summary of gross beta radioactivity concentration in air, April 1974—continued

Location		Number of samples	Concentration (pCi/m³)		
			Maximum	Minimum	Average
Nev:	Ely	13	.6	.2	.4
	Eureka	13	.9	<.1	.4
	Fallini's Twin Springs Ranch	13	.9	<.1	.5
	Fallon	3	.6	.2	.4
	Frenchman Station	3	.3	<.1	.1
	Geyser Ranch (Pioche)	6	.7	.4	.5
	Goldfield	13	1.1	.1	.5
	Groom Lake	13	1.0	.3	.6
	Hiko	13	1.0	.3	.6
	Indian Springs	13	.6	.3	.5
	Las Vegas	14	1.0	<.1	.6
	Lathrop Wells	12	.8	<.1	.5
	Lida	12	.9	<.1	.5
	Lovelock	3	.5	<.1	.3
	Lund	13	.8	.2	.5
	Mesquite	13	.7	<.1	.4
	Nyala	13	1.2	.3	.6
	Pahrump	13	.8	<.1	.5
	Pioche	13	.9	.3	.6
	Reno	3	.6	.2	.4
	Round Mountain	13	.9	.3	.5
	Scotty's Junction	13	.9	.2	.5
	Stone Cabin Ranch	13	.7	.3	.4
	Sunnyside	13	.6	.2	.4
	Tonopah	13	1.0	.2	.5
	Tonopah Test Range	13	.8	.2	.5
	Warm Springs	4	.8	<.1	.5
	Warm Springs Ranch	13	.8	<.1	.5
	Wells	3	.4	<.1	.3
	Winnemucca	3	.2	<.1	.1
N. Mex:	Albuquerque	3	.7	.4	.5
	Carlsbad	3	.5	.3	.4
Okla:	Muskogee	3	.1	.1	.1
Oreg:	Burns	1	.1	.1	.1
S. Dak:	Aberdeen	3	.3	<.1	.2
	Rapid City	3	.2	<.1	.1
Tex:	Abilene	3	.5	.4	.4
	Amarillo	3	.6	.3	.4
	Austin	3	.5	.2	.4
	Fort Worth	3	.5	.3	.4
Utah:	Bryce Canyon	3	.7	.3	.5
	Cedar City	7	.7	<.1	.4
	Delta	13	.6	<.1	.4
	Dugway	3	.4	.2	.3
	Enterprise	3	.7	.2	.4
	Garrison	13	.9	.2	.5
	Logan	3	.5	.1	.2
	Milford	13	1.8	0.2	0.5
	Monticello	3	.3	.2	.2
	Parowan	3	.5	.3	.4
	Provo	3	.3	.1	.2
	St. George	12	.8	.1	.6
	Vernal	3	.4	.2	.3
	Wendover	2	.2	.2	.2
Wash:	Seattle	3	.1	<.1	.1
	Spokane	[illegible]	.6	.1	.3
Wyo:	Rock Springs	[illegible]	.2	.1	.1
	Worland	[illegible]	.3	.2	.2

3. Canadian Air and Precipitation Monitoring Program,[2] April 1974

Radiation Protection Bureau
Department of National Health and Welfare

The Radiation Protection Bureau of the Canadian Department of National Health and Welfare monitors surface air and precipitation in connection with its Radioactive Fallout Study Program. Twenty-four collection stations are located at airports (figure 4), where the sampling equipment is operated by personnel from the Atmospheric Environment Service of the Department of the Environment. Detailed discussions of the sampling procedures, methods of analysis, and interpretation of results of the radioactive fallout program are con-

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[2] Prepared from information and data obtained from the Canadian Department of National Health and Welfare, Ottawa, Canada.

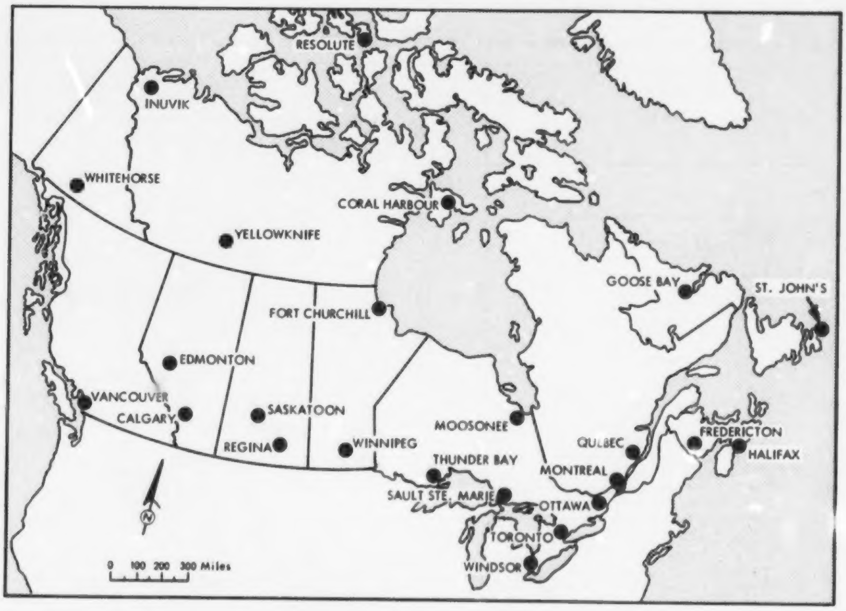
RESOLUTE
INUVIK
WHITEHORSE
CORAL HARBOUR
YELLOWKNIFE
GOOSE BAY
ST. JOHN'S
FORT CHURCHILL
EDMONTON
VANCOUVER
CALGARY
SASKATOON
REGINA
WINNIPEG
MOOSONEE
QUEBEC
FREDERICTON
HALIFAX
THUNDER BAY
MONTREAL
SAULT STE. MARIE
OTTAWA
TORONTO
WINDSOR
N
0 100 200 300 Miles

Figure 4. Canadian air and precipitation sampling stations

Table 3. Canadian gross beta radioactivity in surface air and precipitation, March 1974

Location	Number of samples	Air surveillance gross beta radioactivity (pCi/m³)			Precipitation measurements	
		Maximum	Minimum	Average	Average concentration (pCi/liter)	Total deposition (nCi/m²)
Calgary	5	0.09	0.05	0.07	103.4	5.2
Coral Harbour	5	.12	.05	.08	138.8	2.0
Edmonton	5	.14	.07	.11	121.6	3.3
Ft. Churchill	2	.09	.04	.07	120.2	1.0
Fredericton	5	.17	.05	.11	63.1	8.5
Goose Bay	5	.07	.05	.06	21.6	1.5
Halifax	4	.11	.02	.07	32.1	2.7
Inuvik	5	.11	.04	.08	276.1	.7
Montreal	5	.12	.04	.08	78.4	7.6
Moosonee	4	.14	.08	.11	72.3	3.9
Ottawa	5	.10	.03	.07	110.0	7.4
Quebec	5	.14	.06	.10	74.8	7.8
Regina	5	.14	.06	.10	83.1	1.5
Resolute	5	.10	.03	.07	60.0	.4
St. John's, Nfld	4	.06	.01	.04	25.8	3.9
Saskatoon	5	.15	.05	.10	98.9	1.3
Sault St. Marie	5	.17	.07	.12	89.8	7.2
Thunder Bay	5	.11	.05	.08	85.2	6.2
Toronto	NS				111.8	9.3
Vancouver	5	.09	.03	.06	12.6	1.3
Whitehorse	5	.15	.04	.10	347.7	.7
Windsor	NS				92.5	6.0
Winnipeg	5	.18	.08	.13	65.5	3.8
Yellowknife	5	.09	.06	.08	153.8	.7
Network summary	104	0.18	0.01	0.09	101.6	3.9

NS, no sample.

tained in reports of the Department of National Health and Welfare (*1–5*).

A summary of the sampling procedures and methods of analysis was presented in the May 1969 issue of *Radiological Health Data and Reports*.

Surface air and precipitation data for April 1974 are presented in table 3.

REFERENCES

(*1*) BIRD, P. M., A. H. BOOTH, and P. G. MAR. Annual report of 1959 on the Radioactive Fallout Study Program, CNHW–RP–3. Department of National Health and Welfare, Ottawa, Canada (May 1960).

(*2*) BIRD, P. M., A. H. BOOTH, and P. G. MAR. Annual report for 1960 on the Radioactive Fallout Study Program, CNHW–RP–4. Department of National Health and Welfare, Ottawa, Canada (December 1961).

(*3*) MAR, P. G. Annual report for 1961 on the Radioactive Fallout Study Program, CNHW-RP-5. Department of National Health and Welfare, Ottawa, Canada (December 1962).

(*4*) BEALE, J. and J. GORDON. The operation of the Radiation Protection Division Air Monitoring Program, RPD–11. Department of National Health and Welfare, Ottawa, Canada (July 1962).

(*5*) BOOTH, A. H. The calculation of permissible levels of fallout in air and water and their use in assessing the significance of 1961 levels in Canada, RPD–21. Department of National Health and Welfare, Ottawa, Canada (August 1962).

3. Pan American Air Sampling Program April 1974

Pan American Health Organization and U.S. Environmental Protection Agency

Gross beta radioactivity in air is monitored by countries in the Americas under the auspices of the collaborative program developed by the Pan American Health Organization (PAHO) and the Environmental Protection Agency (EPA) to assist PAHO-member countries in developing radiological health programs.

The air sampling station locations are shown in figure 5. Analytical techniques were described in the March 1968 issue of *Radiological Health Data and Reports*. The April 1974 air monitoring results from the participating countries are given in table 4.

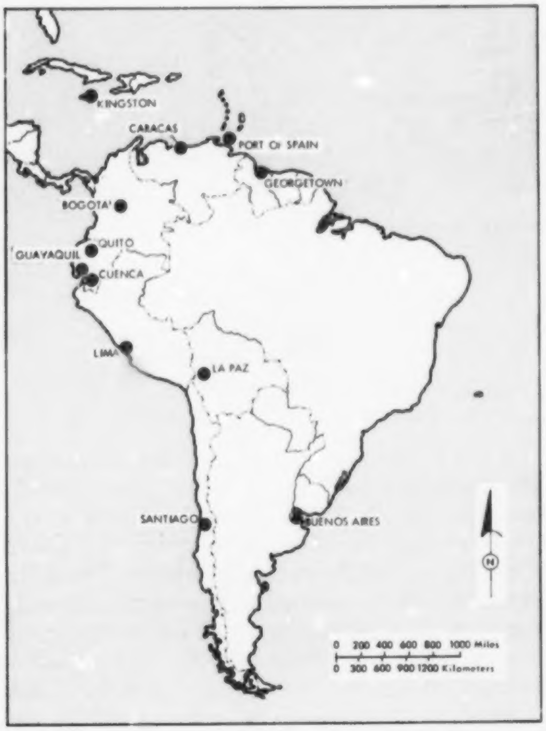

Figure 5. Pan American Air Sampling stations

Table 4. Summary of gross beta radioactivity in Pan American surface air, April 1974

Station location		Number of samples	Gross beta radioactivity (pCi/m³)		
			Maximum	Minimum	Average ᵃ
Argentina:	Buenos Aires	0			
Bolivia:	La Paz	0			
Chile:	Santiago	27	0.04	0.00	0.02
Colombia:	Bogota	18	.09	.00	.02
Ecuador:	Cuenca	7	.01	.00	.00
	Guayaquil	[illegible]	.04	.01	.02
	Quito	[illegible]	.02	.00	.01
Guyana:	Georgetown	[illegible]	.05	.04	.05
Jamaica:	Kingston	0			
Peru:	Lima	17	.02	.00	.01
Trinidad and Tobago:	Port of Spain	0			
Venezuela:	Caracas	4	.04	.01	.03
Pan American summary		101	0.09	0.00	0.02

ᵃ The monthly average is calculated by weighting the individual samples with length of sampling period. Values less than 0.005 pCi/m³ are reported and used in averaging as 0.00 pCi/m³.

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5. California Air Sampling Program April 1974

Radiologic Health Section California Department of Health

The Radiologic Health Section of the California Department of Health with the assistance of several cooperating agencies and organizations operates a surveillance system for determining radioactivity in airborne particulates. The air sampling locations are shown in figure 6.

One of the objectives of the program is to evaluate the possibility that fixed effluent sources contribute to particulate activity in the air. Consequently, data from continuous air samplers placed in proximity to nuclear facilities are compared with those from similar

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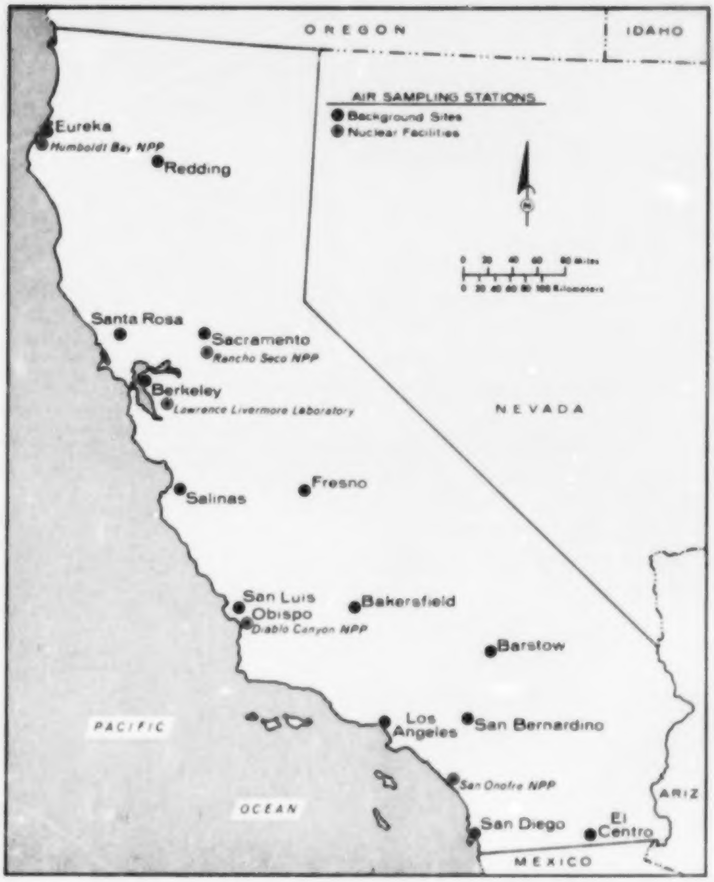
OREGON
IDAHO
AIR SAMPLING STATIONS
● Background Sites
● Nuclear Facilities
0 20 40 60 80 Miles
0 20 40 60 80 100 Kilometers
Eureka
Humboldt Bay NPP
Redding
Santa Rosa
Sacramento
Rancho Seco NPP
Berkeley
Lawrence Livermore Laboratory
NEVADA
Salinas
Fresno
San Luis Obispo
Diablo Canyon NPP
Bakersfield
Barstow
PACIFIC
OCEAN
Los Angeles
San Bernardino
San Onofre NPP
ARIZ
San Diego
El Centro
MEXICO

Figure 6. California air sampling program stations

equipment in nearby communities and at several "background" stations.

Airborne particles are collected by a continuous sampling of air filtered through a 47 millimeter membrane filter, 0.8 micron pore size, using a Gast air pump of about 2 cubic feet per minute capacity, or 81.5 cubic meters per day. Air volumes are measured with a direct reading gas meter. Filters are replaced every 24 hours except on holidays and weekends.

All air samples are sent to the Sanitation and Radiation Laboratory of the State Department of Health. The filters are analyzed for gross alpha and beta radioactivity 72 hours after the end of the collection period. The daily samples then composited into a monthly sample for gamma spectroscopy and an analysis for strontium-89 and strontium-90. The monthly sample results are presented quarterly. Table 5 presents the gross beta radioactivity in air for April 1974.

Table 5. Gross beta radioactivity in California air April 1974

Station location	Number of samples	Gross beta radioactivity (pCi/m³)		
		Maximum	Minimum	Average
Bakersfield	21	1.24	0.10	0.48
Barstow	30	1.06	.12	.61
Berkeley	30	.95	.11	.30
Diablo Canyon Nuclear Power Plant	7	.45	.17	.31
El Centro	20	1.60	.17	.70
Eureka	21	.49	.05	.21
Fresno	19	.90	.13	.46
Humboldt Bay Nuclear Power Plant	3	.11	.02	.06
Livermore	21	.96	.00	.36
Los Angeles	21	.71	.16	.41
Rancho Seco Nuclear Power Plant	13	.77	.16	.36
Redding	16	1.70	.17	.82
Sacramento	22	.61	.10	.29
Salinas	23	.48	.15	.26
San Bernardino	16	.89	.29	.56
San Diego	22	.74	.16	.37
San Luis Obispo	18	.77	.00	.30
San Onofre Nuclear Generating Station	3	.35	.29	.32
Santa Rosa				
Summary	326	1.70	0.00	0.40

6. ERAMS Plutonium and Uranium in Air Component July–September 1973

Office of Radiation Programs
Environmental Protection Agency

The Environmental Radiation Ambient Monitoring System (ERAMS), which began in July 1973, was developed from previously operating radiation montoring networks to form a single monitoring system which is more responsive to current and projected sources of environmental radiation.

The ERAMS Plutonium and Uranium in Air Component is a restructuring of the Plutonium in Airborne Particulates network, which was comprised of monthly plutonium analyses from selected Radiation Alert Network sampling stations. The current sampling stations have been reoriented towards fuel processing, fuel reprocessing, and other facilities using plutonium or uranium. The Plutonium and Uranium in Air Component consists of 19 air sampling stations (figure 7) and are taken from the 19 continuously operated sampling stations of the ERAMS Gross Radioactivity and Deposition Component. Plutonium-238, plutonium-239, uranium-234, and uranium-238 analyses are performed on a quarterly composite from each of the 19 sampling stations by the Eastern Envi-

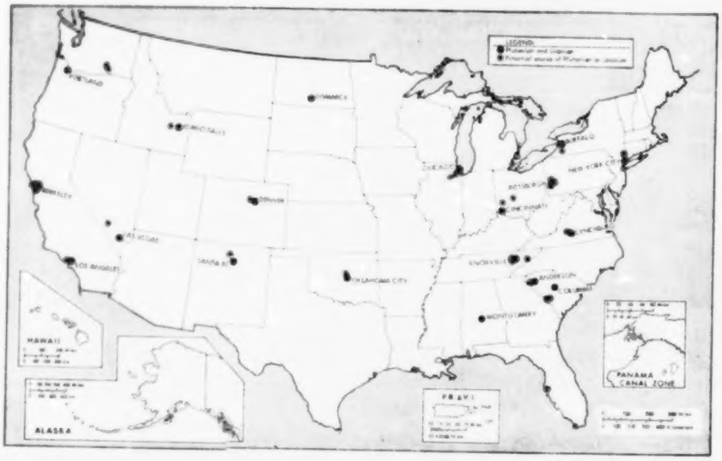

Figure 7. ERAMS Plutonium and Uranium in Air Component sampling stations

Table 6. ERAMS Plutonium and Uranium in Air Component, July-September 1973

Sampling location		Concentration [a] (aCi/m³±2σ)				$^{239}Pu/^{238}Pu$	Potential sources of plutonium or uranium
		^{234}U	^{238}U	^{238}Pu	^{239}Pu		
Ala:	Montgomery	16.7± 1.7	16.0±1.6	1.0±0.4	6.6±0.1	6± 3	Background
Calif:	Berkeley	7.4± 1.0	5.9± .9	.2± .2	4.2± .7	19±14	General Electric Company San Jose, Calif. Lawrence Berkeley Laboratory Berkeley, Calif. Lawrence Livermore Laboratory Livermore, Calif.
	Los Angeles	28.8± 2.3	27.3±2.2	1.1± .3	5.6± .7	5± 1	Atomic International Canoga Park, Calif.
Colo:	Denver	40.8± 3.3	44.9±3.6	1.7± .5	8.4±1.2	5± 2	Rocky Flats Plant Golden, Colo.
Idaho:	Idaho Falls	(b)					National Reactor Testing Station Idaho Falls, Idaho
Ill:	Chicago	(b)					Argonne National Laboratory Lemont., Ill. Midwest Fuel Reprocessing Plant Morris, Ill.
Nev:	Las Vegas	121 ± 7	66 ±4.4	0	8.8±1.2	----------	Nevada Test Site Las Vegas, Nev.
N. Mex:	Santa Fe	19.2± 1.9	19.3±1.9	1.5± .5	6.3±1.0	4± 2	Los Alamos Laboratory Los Alamos, N. Mex.
N.Y:	Buffalo	142 ±10	134 ±9	0	9.5±1.5	----------	Nuclear Fuel Services West Valley, N.Y.
	New York City	(b)					Gulf United Nuclear Fuels Pawling, N.Y.
N. Dak:	Bismarck	28.7± 1.8	30.6±1.9	2.2± .5	8.2±1.2	4± 1	Background
Ohio:	Columbus [c]	82.6± 5.8	79.8±5.6	1.6± .5	7.0±1.1	4± 2	Batelle Columbus Laboratory Columbus, Ohio Mound Laboratory Miamisburg, Ohio
Okla:	Oklahoma City	20.9± 2.0	20.8±2.0	.9± .3	6.5± .9	7± 2	Kerr-McGee Cimarron Plant Cresent, Okla.
Oreg:	Portland	11.6± 1.4	12.4±1.5	1.1± .3	5.6± .8	5± 2	Hanford Laboratories Richland, Wash. Exxon Nuclear Richland, Wash.
Pa:	Harrisburg [d]	24.7± 2.8	20.2±2.5	0	11.3±1.3	----------	Westinghouse Cheswick, Pa. NUMEC—Babcock & Wilcox Leechburgh, Pa.
S.C:	Anderson	(b)					Westinghouse Fuels Recycle Anderson, S.C. Savannah River Plant Aiken, S.C.
	Columbia	53.7± 3.9	48.6±3.5	.8± .2	5.5± .7	7± 2	Allied Gulf Nuclear Fuel Services Barnwell, S.C.
Tenn:	Knoxville	(b)					NFS Fuels Fabrication Plant Erwin, Tenn. Oak Ridge National Laboratory Oak Ridge, Tenn. LMFBR Demonstration Site Oak Ridge, Tenn.
Va:	Lynchburg	(b)					Babcock & Wilcox Lynchburg, Va.
Average		46.0	40.4	0.9	7.2	7	

[a] Any concentration less than the 2σ error has been reported as zero.
[b] Station to be established.
[c] Station to be relocated to Cincinnati.
[d] Station to be relocated to Pittsburgh.

ronmental Radiation Facility, Montgomery, Ala. The volume of the air sampled ranged generally between 700 to 1200 m³/sample. The results from July–September 1973 are shown in table 6. The minimum detectable activities are 20, 15, 15, and 15 fCi per sample for plutonium-238, plutonium-239, uranium-234, and uranium-238, respectively.

Other coverage in *Radiation Data and Reports:*

Period	Issue
July–September 1972	March 1973
October–December 1972	June 1973
January–March 1973	May 1974
April–June 1973	June 1974

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Surface Air Sampling Program—80th Meridian Network[1] January-December 1972

Health and Safety Laboratory
Atomic Energy Commission

The Health and Safety Laboratory (HASL) began its Surface Air Sampling Program in January 1963, as a continuation of the 80th Meridian Program conducted by the U.S. Naval Research Laboratory. The objective of this program is to study the spatial and temporal distribution of nuclear weapons debris and lead in the surface air.

The basic network consists of a line of sites approximately along the 80th meridian extending from about 81° N to 90° S latitudes (figure 1). Since 1963, a number of sites have been added to investigate the possible effects of longitude, elevation, and proximity to coastlines; and from late 1965 through March 1969, samplers were placed on four Atlantic Ocean weather ships to extend the surface air study over the marine environment (table 1).

Table 1. Station location, 1972

Site		Latitude	Longitude (west)	Elevation (meters)
Greenland:	Nord	81° 40′N	17° 00′	250
	Thule	76° 36′N	68° 35′	259
Ontario:	Moosonee	51° 16′N	80° 30′	10
N.Y:	New York City	40° 48′N	73° 58′	38
Utah:	Salt Lake City	40° 46′N	110° 49′	1 516
Colo:	Rocky Flats, No. 1	40° 00′N	105° 11′	1 830
	Rocky Flats, No. 2	40° 00′N	105° 11′	1 738
	Rocky Flats, No. 3	40° 00′N	105° 11′	2 013
Va:	Sterling	38° 58′N	77° 25′	76
Fla:	Miami	25° 49′N	80° 17′	4
Bahamas:	Bimini	25° 46′N	79° 22′	3
Hawaii:	Mauna Loa	19° 28′N	155° 36′	3 401
P.R:	San Juan	18° 26′N	66° 00′	10
Panama:	Balboa	8° 58′N	79° 34′	23
Venezuela:	La Aquada	8° 35′N	71° 9′	3 450
	Merida	8° 36′N	71° 10′	1 570
	Pico Espejo	8° 36′N	71° 10′	4 767
Ecuador:	Guayaquil	2° 10′S	79° 52′	7
Peru:	Lima	12° 01′S	77° 08′	13
Boliva:	Chacaltaya	16° 21′S	68° 07′	5 220
Chile:	Antofagasta	23° 37′S	70° 16′	31
	Isle de Pasqua	27° 10′S	109° 26′	41
	Santiago	33° 27′S	70° 42′	520
	Puerto Montt	41° 27′S	72° 57′	7
	Punta Arenas	53° 08′S	70° 53′	35
Antarctica [a]		62° 56′S	60° 36′	16
		64° 49′S	62° 52′	10
South Pole station		90° 00′S		2 800

[a] The Chilean Antarctic station has moved at least three times within an area of about 2° latitude and longitude. For simplicity, the individual station names were dropped and all data grouped under "Antarctica."

Sampling and analytical procedures

Approximately 1400 cubic meters of ambient air per day are drawn through an 8-inch diameter microsorban filter for the land stations. For the ocean stations, about 2200 cubic meters of air per day were filtered by an 8- by 10-inch microsorban filter. Each filter is changed on the 1st, 8th, 15th, and 22nd of the month or more frequently if the filter becomes clogged with debris suspended in the air.

The filters are returned to HASL at the end of each month and under normal conditions, composited into monthly samples for analysis. Until late 1969, the composited sample was first gamma counted and then sent to a contractor laboratory for radiochemical analysis. In the current program, each sample is split into equal aliquots, one for gamma counting and spectrometry and the other for radiochemistry. Hence, half of each sample is now being kept and stored for possible future work.

Daily pump pressure drop and temperature readings also are submitted to HASL along with the samples for the purposes of computing the volume of sampled air.

Gamma analysis

The gamma activity of half of the monthly composites are obtained with an 8- by 4-inch sodium iodide (Tl) crystal as soon as possible after receipt of the samples. The integrated response between 100 keV and 3.0 MeV is corrected by the average detection efficiency (35 percent) of the gamma photons present in fallout; and the total gamma activities are reported in units of photons per minute per standard cubic meter.

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[1] Summarized from "Fallout Program Quarterly Summary Report," HASL–278 (January 1, 1974) available from the National Technical Information Service, 5285 Port Royal Road, Springfield, Va. 22151.

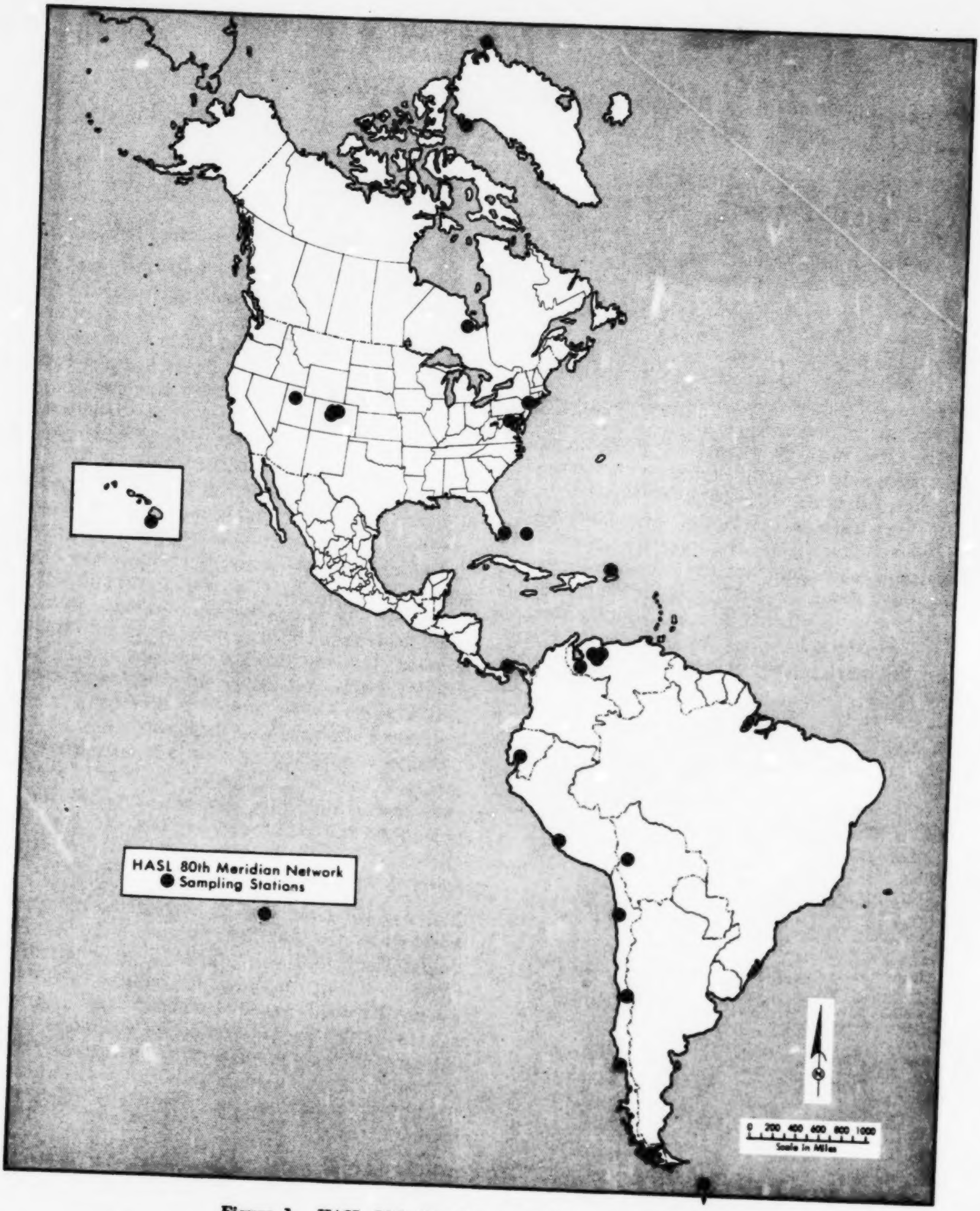
HASL 80th Meridian Network
● Sampling Stations
0 200 400 600 800 1000
Scale in Miles

Figure 1. HASL 80th Meridian Network sampling stations

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Table 2. Strontium-89 concentrations in surface air, HASL, 1972[a]

Site		Strontium-89 concentration (fCi/m^3)											
		Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Greenland:	Nord	1.15	3.32	(c)	1.52	—	—	—	—	—	—	—	—
	Thule	.99	4.13	[b] 1.04	[b] .19	2.39	4.29	3.15	3.30	1.62	.72	.50	[b].37
Ontario:	Moosonee	—	—	—	(c)	5.34	10.90	11.30	8.29	2.66	[b]	—	—
N.Y:	New York City	1.22	4.21	[b] 1.01	[b] 1.81	7.51	11.50	15.20	[b] 9.41	[b] 3.38	1.47	[b].72	[b].29
Utah:	Salt Lake City	17.40	2.66	(c)	10.40	29.90	38.50	28.60	13.10	5.71	3.02	[b].90	[b].90
Colo:	Rocky Flats, No. 1	11.90	1.91	[b] 1.85	8.82	20.50	25.60	13.00	7.28	—	.87	.85	.81
	Rocky Flats, No. 2	—	—	—	—	—	—	18.30	9.97	2.34	1.03	1.19	.57
	Rocky Flats, No. 3	—	—	—	—	—	—	—	—	—	(c)	1.59	.94
Va:	Sterling	3.38	4.16	[b] 1.19	3.65	5.63	12.50	7.30	6.39	2.61	1.67	[b].69	[b].28
Fla:	Miami	—	3.19	2.85	15.30	15.50	11.20	8.91	5.90	2.02	.99	.91	[b].48
Bahamas:	Bimini	—	[b].97	—	—	—	—	—	—	—	—	—	—
Hawaii:	Mauna Loa	8.25	1.72	1.87	33.80	37.70	32.40	17.70	4.44	2.02	.82	.75	[b].40
Puerto Rico:	San Juan	1.27	.98	[b].53	14.30	11.40	—	9.64	4.78	1.53	.33	[b].40	[b].32
Panama:	Balboa	6.30	.95	(c)	4.90	5.74	—	4.22	2.63	[b].57	[b].09	[b].16	(c)
Venezuela:	La Aquada	—	—	—	—	—	—	—	1.02	[b].14	—	—	—
	Merida	—	—	—	—	—	—	—	1.27	.25	—	—	—
	Pico Espejo	—	—	—	—	—	—	.91	.36	(c)	.16	[b].30	[b].30
Ecuador:	Guayaquil	.96	.91	(c)	.58	[b].24	[b] 0.25	.32	4.01	[b].66	[b].35	[b].24	(c)
Peru:	Lima	25.20	9.08	10.30	3.62	[b] 1.42	1.23	8.77	9.08	[b] 3.09	[b].40	[b].65	(c)
Bolivia:	Chacaltaya	5.74	4.70	1.36	1.39	2.06	3.27	3.59	14.90	.27	[b].69	[b].33	[b].22
Chile:	Antofagasta	10.40	11.00	7.11	2.88	2.13	1.71	38.00	22.30	1.99	[b].79	1.09	[b] 2.39
	Isle de Pasqua	6.28	4.43		1.58	1.19	[b].38	1.55	1.03	[b].40	[b].20	[b].13	[b].59
	Santiago	—	4.73	[b] 5.22	[b] 4.83	[b].69	2.14	22.30	5.80	.99	[b] 3.03	(c)	(c)
	Puerto Montt	7.82	[b] 7.47	6.95	3.67	[b] 1.24	.73	[b].64	.76	[b] 1.03	—	.20	[b].70
	Punta Arenas	—	—	—	—	—	—	—	.46	[b].20	—	(c)	(c)
South Pole station		15.20	(c)	[b] 8.56	5.92	[b] 2.12	[b] 1.11	[b].33	.90	[b].98	—	[b].38	(c)

[a] Errors are less than 20 percent except:
[b] Error between 20—100 percent;
[c] Error greater than 100 percent.
—. no data reported.

Gamma spectra of the monthly composites are obtained using a lithium-drifted germanium diode (GeLi) system. Concentrations of the gamma emitting nuclides, beryllium-7, zirconium-95, cesium-137, and cerium-144 are determined by computer resolution of the spectra. Beginning in June 1970, all results from these nuclides, reported in the tables, were obtained using this system.

Table 3. Strontium-90 concentrations in surface air, HASL, 1972[a]

Site		Strontium-90 concentration (fCi/m^3)											
		Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Greenland:	Nord	0.61	0.64	1.04	1.20	—	—	—	—	—	—	—	—
	Thule	.69	1.09	1.73	.98	1.01	.68	.42	.44	.36	.27	.38	.49
Ontario:	Moosonee	—	—	—	1.81	1.04	1.39	1.58	1.07	.42	—	—	—
N.Y:	New York City	.29	.99	1.35	1.58	1.48	1.61	1.68	1.25	.82	.51	.33	[b].36
Utah:	Salt Lake City	1.74	1.56	2.96	2.72	3.48	3.22	2.48	2.00	1.46	.36	.72	[b].50
Colo:	Rocky Flats, No. 1	1.20	1.32	2.37	2.08	1.64	1.72	1.16	.96	—	.34	.38	.59
	Rocky Flats, No. 2	—	—	—	—	—	—	[b].89	1.31	.67	.41	.46	.52
	Rocky Flats, No. 3	—	—	—	—	—	—	—	—	—	1.01	.54	.61
Va:	Sterling	.80	.95	1.14	1.82	.77	1.57	.73	.75	.56	.69	.24	.27
Fla:	Miami	—	1.28	1.58	2.95	1.08	1.01	.98	.73	.45	.42	.40	.50
Bahamas:	Bimini	—	1.40	—	—	—	—	—	—	—	—	—	—
Hawaii:	Mauna Loa	2.05	2.09	1.60	2.12	2.32	1.96	1.66	.66	.58	.47	.41	.57
Puerto Rico:	San Juan	.63	.74	.97	1.89	1.19	—	.99	.73	.39	.17	.32	.23
Panama:	Baboa	.79	.64	.81	1.10	.34	—	.43	.42	[b].11	[b].06	.11	.31
Venezuela:	La Aquada	—	—	—	—	—	—	—	.17	.10	—	—	—
	Merida	—	—	—	—	—	—	—	.18	.11	—	—	—
	Pico Espejo	—	—	—	—	—	—	.07	.09	.04	.04	[b].10	.33
Ecuador:	Guayaquil	.18	.19	.14	.25	.13	.12	[b].03	.14	.28	.38	.29	.35
Peru:	Lima	3.59	1.54	1.91	1.10	.40	.77	.58	.78	3.36	1.44	2.01	1.49
Bolivia:	Chacaltaya	.58	.83	.33	.40	.61	.76	.49	.76	.50	1.19	.70	.41
Chile:	Antofagasta	1.73	2.06	1.99	1.57	.78	1.12	1.65	1.69	1.71	1.65	1.34	.47
	Isle de Pasqua	1.00	.98	—	.42	.44	.38	.47	.66	.67	.60	.61	.35
	Santiago	—	1.13	2.33	1.30	.77	.91	1.01	1.07	1.51	1.87	1.59	1.29
	Puerto Montt	1.43	2.37	1.52	.67	.70	.45	.41	.54	.64	—	.40	.47
	Punta Arenas	—	—	—	—	—	—	—	.27	.31	.26	.25	.40
South Pole station		3.48	1.77	1.19	.93	.85	.84	.34	.62	.87	.79	.85	.20

[a] Errors are less than 20 percent except:
[b] Error between 20—100 percent;
—, no data reported.

Radiochemical analyses

The other halves of the monthly composites are sent to a contractor laboratory for radiochemical analyses.

There were no major weapon test series from the end of 1962 until May 1966. Consequently, only the longer-lived artificially produced radionuclides were present in the filters collected during this period and emphasis was given to the determination of manganese-54, iron-55, strontium-90, cadmium-109, cesium-137, cerium-144, plutonium-238, and plutonium-239. In samples collected after French or Chinese atmospheric weapons tests additional short-lived nuclides were analyzed, such as strontium-89, zirconium-95, and cerium-141.

The longer-lived fission products and plutonium-239 concentrations should describe the general distribution in surface air in all previous nuclear weapon debris which was transferred from the lower stratosphere to the troposphere during the collection period of this report. Other tracer nuclides can be associated with debris from a single detonation or series of detonations. Manganese-54 and iron-55 were produced in large quantities in the 1961 and 1962 test series. Cadmium-109 was generated by the U.S. high altitude test over Johnston Island on July 9, 1962. While plutonium-238 is present in low concentrations in nuclear weapons debris, about 17 000 curies of plutonium-238 was disseminated at high altitude in the stratosphere on April 21, 1964 during the reentry burnup of a SNAP–9A power source.

As the levels of any of the radionuclides drop to below practical detection limits they are eliminated from the radiochemical program; thus, cadmium-109 was not analyzed after the end of 1967.

Most of the analyses of surface air samples were carried out from July 1969 to the present by the LFE-Environmental Analysis Laboratories.

Results

The radioactivity concentrations in surface air during January–December 1972 are presented in tables 2 through 8. The sites are listed according to latitude beginning with the

Table 4. Zirconium-95 concentrations in surface air, HASL, 1972[a]

Site		Zirconium-95 concentration (fCi/m³)											
		Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Greenland:	Nord	2.27	[b]2.47	[b]0.82	4.54	—	—	—	—	—	—	—	—
	Thule	2.21	[b]1.52	[b]1.44	6.70	20.10	20.50	7.05	4.23	(c)	[b]0.43	(c)	(c)
Ontario:	Moosonee	—	—	—	24.60	22.40	28.20	12.60	7.37	[b]1.18	—	—	—
N.Y:	New York City	[b]8.39	2.85	[b]1.81	81.40	25.60	24.50	13.40	5.81	2.83	[b].67	(c)	[b]0.82
Utah:	Salt Lake City	60.90	6.04	[b]4.55	86.70	82.40	51.40	27.80	9.55	4.41	[b]2.18	[b]1.04	(c)
Colo:	Rocky Flats, No. 1	34.20	3.45	5.33	80.80	57.10	30.20	13.10	[b]9.10	—	(c)	[b].90	[b]1.29
	Rocky Flats, No. 2	—	—	—	—	—	—	13.50	7.87	[b]1.50	(c)	(c)	(c)
	Rocky Flats, No. 3	—	—	—	—	—	—	—	—	—	[b]3.96	[b]1.15	[b].41
Va:	Sterling	9.67	2.71	1.53	26.10	19.00	24.40	11.50	4.50	(c)	[b].79	[b].45	(c)
Fla:	Miami	[b]8.63	2.96	3.26	120.00	41.90	16.50	8.52	5.20	2.13	[b]1.08	[b].45	[b].56
Hawaii:	Mauna Loa	7.49	[b]4.92	2.85	145.00	91.00	34.90	15.10	(c)	(c)	(c)	(c)	(c)
Puerto Rico:	San Juan	(c)	2.42	[b]1.77	59.70	36.00	—	10.40	12.20	1.35	[b].31	(c)	2.01
Panama:	Balboa	2.66	[b]2.66	1.59	4.87	8.51	—	4.45	2.13	[b].91	(c)	(c)	(c)
Venezuela:	La Aquada	—	—	—	—	—	—	—	—	—	(c)	(c)	(c)
	Merida	—	—	—	—	—	—	—	—	—	(c)	(c)	[b].30
	Pico Espejo	—	—	—	—	—	—	—	—	—	(c)	(c)	[b].48
Ecuador:	Guayaquil	8.72	3.99	(c)	3.08	1.23	1.60	[b]2.97	10.20	[b]4.31	—	[b].39	(c)
Peru:	Lima	71.90	21.80	14.40	12.10	2.68	5.31	13.50	33.60	6.14	[b]1.48	[b]2.11	[b].71
Bolivia:	Chacaltaya	10.30	10.50	2.33	[b]4.70	4.89	4.56	6.28	20.30	—	(c)	[b].68	(c)
Chile:	Antofagasta	28.90	23.10	19.90	11.10	4.19	6.95	53.70	57.60	2.84	[b]2.09	[b]1.44	(c)
	Isle de Pasqua	12.20	12.10	—	3.33	3.62	[b]1.80	[b]12.50	[b]2.09	3.51	(c)	[b].60	(c)
	Santiago	44.70	20.30	23.70	16.10	5.59	6.05	31.30	[b]11.70	3.37	[b]1.14	[b]3.48	(c)
	Puerto Montt	21.50	21.90	16.70	7.18	4.06	[b]2.16	[b]1.19	[b]4.86	[b]4.83	—	(c)	5.12
	Punta Arenas	—	—	—	—	—	—	—	—	—	(c)	—	(c)
Antarctica		(c)	—	—	—	—	(c)	—	—	—	—	—	—
	South Pole station	36.20	[b]18.00	[b]13.20	[b]2.64	3.99	[b]1.81	(c)	[b]1.81	[b]1.03	[b].90	(c)	[b].47

[a] Errors are less than 20 percent except:
[b] Error between 20—100 percent;
[c] Error greater than 100 percent.
—, no data reported.

Table 5. Cesium-137 concentrations in surface air, HASL, 1972[a]

Site		Cesium-137 concentration (fCi/m³)											
		Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Greenland:	Nord	1.21	1.19	1.57	2.27	—	—	—	—	—	—	—	—
	Thule	1.24	1.21	2.31	1.54	1.77	1.48	0.74	1.04	0.57	0.37	0.42	0.87
Ontario:	Moosonee	—	—	—	2.69	2.93	2.60	1.84	1.70	.73	—	—	—
N.Y:	New York City	[b]2.44	1.84	2.14	3.17	2.83	2.62	2.22	1.56	1.24	.79	.62	.57
Utah:	Salt Lake City	4.08	3.16	4.03	4.50	6.55	1.97	4.61	2.97	1.99	1.11	[b]1.03	[b].66
Colo:	Rocky Flats, No. 1	2.00	2.00	3.44	2.99	3.30	2.77	2.03	1.90	—	.65	.70	.79
	Rocky Flats, No. 2	—	—	—	—	—	—	2.46	1.93	.96	.65	.71	.76
	Rocky Flats, No. 3	—	—	—	—	—	—	—	—	—	.75	.97	.98
Va:	Sterling	1.73	1.91	2.04	2.89	[illegible]	2.51	[illegible]	1.15	.90	.75	.36	.45
Fla:	Miami	2.37	2.32	3.47	5.[illegible]	2.95	1.98	1.54	1.48	.87	.80	.63	.45
Bahamas:	Bimini	—	2.42	—	—	—	—	—	—	—	—	—	—
Hawaii:	Mauna Loa	3.44	3.77	2.25	6.27	3.44	2.61	2.25	1.48	[b].89	.69	.43	1.12
Puerto Rico:	San Juan	[b]1.05	1.59	[b]2.25	2.94	1.97	—	1.44	2.62	.62	.51	.47	.46
Panama:	Balboa	1.10	[b]1.73	1.25	1.96	.65	—	1.66	.53	[b].25	[b].09	[b].17	[b].14
Venezuela:	La Aquada	—	—	—	—	—	—	—	—	—	[c].22	[b].06	.55
	Merida	—	—	—	—	—	—	—	—	—	.19	[b].10	[b].33
	Pico Espejo	—	—	—	—	—	—	—	—	—	[b].10	[b].17	.59
Ecuador:	Guayaquil	.88	.53	(c)	[b].29	[b].26	.33	.50	.32	[b].31	.56	.70	.28
Peru:	Lima	6.32	2.25	2.16	2.30	.62	1.19	1.27	1.51	4.12	2.07	2.90	1.84
Bolivia:	Chacaltaya	[b].88	[b].90	.47	[b].70	[b]1.08	.93	.78	1.43	.82	2.05	.94	.66
Chile:	Antofagasta	3.05	2.97	[b]2.50	2.08	1.07	1.50	2.80	2.32	2.17	2.15	2.04	1.23
	Isle de Pasqua	1.49	1.39	—	.76	.95	.56	.50	1.13	1.12	.99	.85	.51
	Santiago	5.11	2.26	3.13	2.96	1.25	1.46	1.92	[b]1.67	2.38	3.16	3.64	2.67
	Puerto Montt	2.54	3.08	2.50	1.23	.71	.56	.51	.79	1.23	—	.69	[b].21
	Punta Arenas	—	—	—	—	—	—	—	.49	.51	.34	.45	.54
Antarctica		(c)	—	—	—	—	.29	—	—	—	—	—	—
South Pole station		5.20	2.25	2.07	1.25	1.03	.94	.50	.81	.92	1.05	1.24	1.00

[a] Errors are less than 20 percent except:
[b] Error between 20—100 percent;
[c] Error greater than 100 percent.
—, no data reported.

Table 6. Cerium-144 concentrations in surface air, HASL, 1972[a]

Site		Cerium-144 concentration (fCi/m³)											
		Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Greenland:	Nord	7.56	6.60	8.97	11.90	—	—	—	—	—	—	—	—
	Thule	10.60	8.41	14.40	8.26	13.10	11.80	6.23	5.62	3.82	1.72	2.29	3.02
Ontario:	Moosonee	—	—	—	22.40	18.00	19.50	12.10	10.90	3.47	—	—	—
N.Y:	New York City	[b]16.40	11.70	12.80	27.40	19.30	19.50	15.70	9.11	6.65	3.49	2.15	1.76
Utah:	Salt Lake City	34.80	19.90	24.60	37.20	45.60	38.70	30.70	15.30	10.20	4.74	5.43	3.13
Colo:	Rocky Flats, No. 1	20.70	12.10	18.80	27.10	30.70	23.30	14.90	9.28	—	2.55	2.64	2.57
	Rocky Flats, No. 2	—	—	—	—	—	—	15.10	10.40	4.54	3.05	2.97	2.74
	Rocky Flats, No. 3	—	—	—	—	—	—	—	—	—	2.85	3.95	3.55
Va:	Sterling	14.70	11.70	11.60	22.80	16.60	18.80	11.80	6.92	4.64	3.68	1.68	1.34
Fla:	Miami	13.30	14.30	21.00	46.30	23.60	13.20	9.68	7.83	3.97	4.53	2.05	2.73
Bahamas:	Bimini	—	17.40	—	—	—	—	—	—	—	—	—	—
Hawaii:	Mauna Loa	27.10	19.70	12.70	56.30	42.00	21.80	14.00	6.55	3.59	2.30	2.14	3.76
Puerto Rico:	San Juan	9.53	8.36	13.00	26.10	17.60	—	10.50	15.70	2.58	1.87	1.46	1.28
Panama:	Balboa	7.17	6.71	7.42	11.20	5.05	—	5.53	3.04	[b]1.12	[b].72	[b].74	[b]1.55
Venezuela:	La Aquada	—	—	—	—	—	—	—	—	—	[b].67	[b].33	1.42
	Merida	—	—	—	—	—	—	—	—	—	.83	[b].79	1.12
	Pico Espejo	—	—	—	—	—	—	—	—	—	[b].57	[b].80	1.67
Ecuador:	Guayaquil	9.93	6.07	1.43	4.55	2.63	2.30	3.74	3.78	[b]2.49	3.53	4.54	[b].94
Peru:	Lima	80.10	25.40	26.10	23.80	5.33	12.20	10.50	14.40	30.90	13.70	17.30	10.60
Bolivia:	Chacaltaya	12.00	13.90	3.18	6.12	8.87	10.40	5.80	10.70	5.37	10.90	4.54	2.93
Chile:	Antofagasta	35.70	35.20	29.70	22.30	10.20	14.30	26.80	25.30	14.90	14.90	12.40	8.30
	Isle de Pasqua	13.20	15.90	—	6.65	7.01	4.48	6.81	7.21	6.13	6.30	5.57	2.57
	Santiago	47.30	26.40	31.10	24.70	11.40	12.00	15.80	18.20	16.20	18.30	22.20	13.00
	Puerto Montt	31.30	35.70	21.00	12.70	7.68	5.11	4.61	6.56	6.99	—	3.05	2.90
	Punta Arenas	—	—	—	—	—	—	—	3.38	4.20	1.74	2.25	2.83
Antarctica		[b]3.74	—	—	—	—	4.59	—	—	—	—	—	—
South Pole station		48.70	19.80	14.80	11.00	10.10	8.52	3.86	5.51	6.19	6.54	6.71	4.92

[a] Errors are less than 20 percent except:
[b] Error greater than 100 percent.
—, no data reported.

Table 7. Plutonium-238 concentrations in surface air, HASL, 1972[a]

Site		Plutonium-238 concentration (aCi/m³)											
		Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Greenland:	Nord	(c)	(c)	[b] 1.84	[b] 2.65	—	—	—	—	—	—	—	—
	Thule	(c)	(c)	[b] 4.17	(c)	[b] 1.63	(c)	(c)	(c)	(c)	(c)	[b] 2.92	(c)
Ontario:	Moosonee	—	—	—	(c)	[b] 2.51	[b] 2.29	[b] 2.60	[b] 1.31	(c)	—	—	—
N.Y:	New York City	12.00	[b] 4.16	[b] 2.25	[b] 3.59	[b] 15.20	8.44	9.12	(c)	46.30	9.08	[b] 3.87	[b] 9.82
Utah:	Salt Lake City	[b] 3.38	[b] 7.18	[b] 4.12	[b] 3.54	10.00	[b] 5.67	[b] 10.40	(c)	[b] 3.81	[b] 2.38	(c)	—
Colo:	Rocky Flats, No. 1	105.00	37.70	97.90	32.20	49.10	131.00	98.60	30.10	—	33.70	[b] 9.30	35.10
	Rocky Flats, No. 2	—	—	—	—	—	—	[b] 4.32	(c)	[b] 3.51	[b] 7.54	(c)	(c)
	Rocky Flats, No. 3	—	—	—	—	—	—	—	—	—	(c)	(c)	(c)
Va:	Sterling	(c)	(c)	[b] 2.37	[b] 2.01	[b] 2.20	[b] 1.97	[b] 2.04	[b] 6.46	(c)	(c)	—	(c)
Fla:	Miami	[b] 8.56	(c)	[b] 3.54	[b] 6.06	(c)	(c)	(c)	(c)	[b] 1.35	(c)	(c)	(c)
Bahamas:	Bimini	—	[b] 2.06	—	—	—	—	—	—	—	—	(c)	(c)
Hawaii:	Mauna Loa	[b] 4.02	(c)	(c)	[b] 4.66	[b] 7.06	[b] 4.08	[b] 1.80	(c)	—	(c)	(c)	(c)
Puerto Rico:	San Juan	(c)	(c)	(c)	[b] 3.24	[b] 1.51	—	[b] 1.37	(c)	(c)	(c)	(c)	(c)
Panama:	Balboa	[b] 2.40	(c)	[b] 2.03	[b] 2.97	(c)	—	[b] 1.41	(c)	(c)	(c)	(c)	(c)
Venezuela:	La Aquada	—	—	—	—	—	—	—	(c)	(c)	—	—	—
	Merida	—	—	—	—	—	—	—	(c)	[b] 7.07	—	—	—
	Pico Espejo	—	—	—	—	—	—	(c)	(c)	(c)	(c)	(c)	(c)
Ecuador:	Guayaquil	(c)	(c)	—	(c)	(c)	(c)	13.40	[b] 2.70	(c)	(c)	(c)	[b] 6.47
Peru:	Lima	[b] 4.76	(c)	2.38	[b] 1.63	(c)	[b] 2.36	[b] 5.59	(c)	[b] 7.42	[b] 3.21	[b] 2.29	—
Bolivia:	Chacaltaya	(c)	(c)	(c)	(c)	(c)	[b] 2.94	[b] 2.05	9.58	(c)	(c)	(c)	[b] 8.03
Chile:	Antogagasta	1.64	(c)	(c)	[b] 3.05	[b] 2.17	(c)	[b] 4.40	20.10	236.00	[b] 1.62	[b] 8.44	[b] 7.08
	Isle de Pasqua	(c)	[b] 2.18	—	(c)	(c)	[b] 1.16	[b] 5.09	(c)	[b] 2.12	(c)	[b] 1.77	(c)
	Santiago	[b] 3.49	[b] 3.76	(c)	(c)	(c)	[b] 3.80	20.10	[b] 9.73	[b] 5.31	(c)	(c)	(c)
	Puerto Montt	22.90	[b] 4.75	(c)	(c)	[b] 1.96	(c)	[b] 3.67	[b] 2.07	(c)	—	(c)	(c)
	Punta Arenas	—	—	—	—	—	—	—	(c)	(c)	(c)	[b] .56	(c)
South Pole station		[b] 3.39	(c)	(c)	(c)	(c)	(c)	(c)	(c)	[b] 1.30	(c)	(c)	(c)

[a] Errors are less than 20 percent except:
[b] Error between 20—100 percent;
[c] Error greater than 100 percent.
—, no data reported.

Table 8. Plutonium-239 concentrations in air, HASL, 1972[a]

Site		Plutonium-239 concentration (aCi/m³)											
		Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Greenland:	Nord	[b] 9.57	17.70	21.30	29.20	—	—	—	—	—	—	—	—
	Thule	9.88	29.00	39.80	18.20	26.10	23.50	11.80	13.00	9.64	12.10	8.42	11.90
Ontario:	Moosonee	—	—	—	32.80	35.90	44.60	36.80	31.10	13.50	—	—	—
N.Y:	New York City	23.50	23.60	26.20	[b] 31.10	36.90	48.70	[b] 47.80	38.60	20.40	15.00	[b] 9.18	[b] 5.31
Utah:	Salt Lake City	106.00	43.70	52.10	52.90	93.90	91.70	105.00	[b] 96.90	42.20	17.20	[b] 15.40	[b] 10.50
Colo:	Rocky Flats, No. 1	5 430.00	1 670.00	4 610.00	1 460.00	2 080.00	6 610.00	4 720.00	1 380.00	—	1 620.00	498.00	1 860.00
	Rocky Flats, No. 2	—	—	—	—	—	—	99.00	55.50	119.00	508.00	48.50	45.20
	Rocky Flats, No. 3	—	—	—	—	—	—	—	—	—	21.90	18.50	25.60
Va:	Sterling	27.00	24.60	26.40	30.80	33.80	35.70	34.00	[b] 15.50	15.80	13.80	(c)	(c)
Fla:	Miami	[b] 39.50	35.30	59.30	61.80	44.00	23.70	24.80	24.80	15.00	15.80	12.20	11.70
Bahamas:	Bimini	—	42.40	—	—	—	—	—	—	—	—	—	—
Hawaii:	Mauna Loa	124.00	39.00	29.70	49.30	76.10	65.00	43.60	[b] 28.50	—	13.50	[b] 14.00	43.00
Puerto Rico:	San Juan	11.90	15.50	21.20	39.10	30.20	—	25.80	20.10	12.40	4.98	7.84	[b] 4.48
Panama:	Balboa	10.10	12.10	16.60	17.40	10.40	—	12.60	[b] 29.40	[b] 3.24	[b] 1.10	[b] 2.11	5.63
Venezuela:	La Aquada	—	—	—	—	—	—	—	[b] 8.86	[b] 2.15	—	—	—
	Merida	—	—	—	—	—	—	—	8.25	4.05	—	—	—
	Pico Espejo	—	—	—	—	—	—	5.60	[b] 1.12	(c)	[b] 3.97	[b] 3.70	[b] 14.30
Ecuador:	Guayaquil	6.09	5.48	4.74	3.76	4.82	[b] 5.32	230.00	45.30	[b] 4.92	6.78	[b] 6.40	[b] 8.09
Peru:	Lima	80.60	18.20	27.30	15.40	7.37	12.10	104.00	[b] 93.10	43.70	23.80	37.50	22.80
Bolivia:	Chacaltaya	[b] 7.34	10.60	[b] 4.18	6.06	11.70	13.00	23.50	137.00	8.23	20.80	[b] 10.50	13.10
Chile:	Antofagasta	18.20	27.10	19.20	22.50	14.30	[b] 21.00	44.00	319.00	27.80	29.10	21.70	23.60
	Isle de Pasqua	10.20	10.10	—	4.53	6.19	4.55	81.50	14.70	8.69	10.90	15.80	15.50
	Santiago	25.30	29.80	25.80	22.80	[b] 15.60	52.50	294.00	66.10	32.00	36.40	38.50	32.40
	Puerto Montt	138.00	26.40	16.70	9.07	7.95	7.22	8.59	14.50	[b] 14.30	—	8.15	9.70
	Punta Arenas	—	—	—	—	—	—	—	8.51	[b] 4.22	[b] 3.78	12.80	10.80
South Pole station		40.90	20.70	12.30	9.84	14.60	8.50	5.29	9.89	12.60	10.00	9.04	[b] 3.92

[a] Errors are less than 20 percent except:
[b] Error between 20—100 percent;
[c] Error greater than 100 percent.
—, no data reported.

most northern site at Nord, Greenland (table 1).

The concentrations are reported at the midpoint of the collection month for the plutonium isotopes and the fission products.

One standard deviation of the counting error for these data is always less than ±20 percent unless otherwise indicated.

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SECTION IV. OTHER DATA

This section presents results from routine sampling of biological materials and other media not reported in the previous sections. Included here are such data as those obtained from human bone sampling, Alaskan surveillance and environmental monitoring around nuclear facilities.

Environmental Levels of Radioactivity at Atomic Energy Commission Installations

The U.S. Atomic Energy Commission (AEC) receives from its contractors annual reports on the levels of environmental contaminants including radioactivity in the vicinity of major Commission installations. The reports include data from routine monitoring programs where operations are of such a nature that plant environmental surveys are required. The complete environmental monitoring reports are available in a compendium report entitled "Environmental Monitoring at Major U.S. Atomic Energy Commission Contractor Sites, Calendar year 1972," WASH–1259. The portions of these reports dealing with radioactivity are summarized for *Radiation Data and Reports*. Statements interpreting the radioactivity data are those of the USAEC contractors. The units for the data as reported in WASH–1259 have been converted from the format required by the AEC to that used by *Radiation Data and Reports*. The Environmental Protection Agency has not independently nor critically reviewed the data or the conclusions derived therefrom.

Releases of radioactive materials from AEC installations are governed by radiation standards set forth by AEC's Division of Operational Safety in directives published in the "AEC Manual." [1]

Summaries of the environmental radioactivity data follow for Feed Materials Production Center and Knolls Atomic Power Laboratory.

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[1] Title 10, Code of Federal Regulations, Part 20, "Standards for Protection Against Radiation" contains essentially the standards published in Chapter 0524 of the AEC Manual.

I. Feed Materials Production Center,[2] January–December 1972

National Lead Company
Fernald, Ohio

The Feed Materials Production Center (FMPC) is operated by the National Lead Company of Ohio for the Atomic Energy Commission (AEC). The location as related to populated areas is shown in figure 1. Cincinnati and Hamilton, the larger nearby communities, are situated 32 and 16 km from the center, respectively.

The primary work at the FMPC is the production of purified uranium metal and compounds for use at other AEC sites. A small amount of thorium is also processed.

Uranium production may begin with ore concentrates, recycled uranium from spent reactor fuel, or with various compounds from other AEC sites. Impure starting material is dissolved in nitric acid and the uranium is extracted into an organic liquid and then back-extracted into dilute nitric acid to yield a solution of uranyl nitrate.

Evaporation and heating convert the nitrate solution to uranium trioxide (UO_3) powder. This componnd is reduced to uranium dioxide (UO_2) with hydrogen and then converted to uranium tetrafluoride (UF_4) by reaction with anhydrous hydrogen fluoride. Uranium metal is produced by reacting UF_4 and magnesium metal in a refractory-lined reduction vessel.

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[2] Summarized from "Environmental Monitoring at Major U.S. Atomic Energy Commission Contractor Sites; Feed Materials Production Center, 1972."

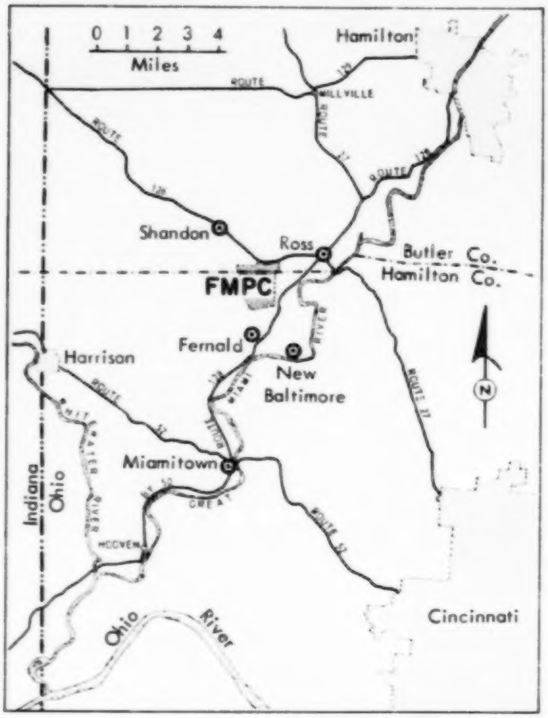

Figure 1. Area map of Feed Materials Production Center

This primary uranium metal is then remelted with scrap uranium metal to yield a purified uranium ingot which is rolled or extruded to form rods or tubes. Sections are then cut and machined to final dimensions. These machined cores are then shipped to other AEC sites for canning and final assembly into reactor fuel elements.

Thorium production steps, in general, are similar to those followed in uranium production. Final products may be purified thorium nitrate solution, solid thorium compounds, or metal.

Air monitoring

Conversion of impure uranium and thorium compounds to reactor-grade feed materials involves operations which generate radioactive dust, nuisance dusts, and corrosive mists or reaction products. Ventilation and air cleaning systems are used to confine this air and remove airborne contaminants, including valuable material which is returned to the production processes. The filtered or scrubbed air is exhausted to the atmosphere. Sampling of these stack exhausts is maintained on a continuous schedule to determine the operating condition of the air cleaning systems.

During 1972, samples of particulate matter in air were continuously collected at six permanent sampling stations located on the project's outer boundary (figure 2). At each boundary station, a metered quantity of air is drawn through a filter which is changed weekly. Filters are weighed before use and then reweighed after changing to obtain the weight of collected dust. After reweighing, the filter and its collection of dust is dissolved in acid and the solutions are analyzed for uranium and alpha and beta radioactivity. After these analyses are completed the remaining solution is held to provide a long-term composite for thorium analyses. Frequent thorium analyses are not considered necessary because of the small amount of thorium processed and the low concentration of thorium found in the boundary samples.

Table 1 shows that the average radionuclide concentrations in air, and at boundary sampling stations, were no greater than 0.4 percent of their respective standards for offsite areas. It is concluded from these data that any offsite radiation exposure resulting from FMPC airborne contaminants would be a small fraction of the AEC standards (*1*).

Water monitoring

Each of the individual production plants on the project has sumps and equipment for the collection and initial treatment of process waste water. Uranium and thorium may be recovered as part of the treatment. Effluents from the plants are collected at a central facility, called the general sump, for additional treatment. The treated wastes are then discharged into a large pit where the solids settle to the bottom. Clear effluent from the pit is combined with the other water streams and discharged to the Great Miami River.

Water samples are collected at several points to determine the effect of the effluent upon the

Table 1. Radioactivity levels of airborne particulates, Feed Material Production Center, December 1972

Contaminant	Sampling point	Number of samples	Radionuclide concentration							95-percent confidence limit	Detection level
			Maximum		Minimum		Average		Percent of standard		
			(fCi/m³)	(ng/m³)	(fCi/m³)	(ng/m³)	(fCi/m³)	(ng/m³)			
Uranium [a]	BS 1	41	14.2	43	0.4	1	6.0	18	0.3	±5 fCi/m³	10 fCi/m³
	BS 2	44	54.4	162	.4	1	6.0	18	.3		
	BS 3	40	14.5	44	.9	3	9.1	27	.4		
	BS 4	46	14.9	45	.6	2	2.8	8	.1		
	BS 5	42	7.7	23	.7	2	3.5	11	.2		
	BS 6	43	19.0	57	1.2	4	6.8	22	.3		
Thorium [b]	BS 1	[d] 1	NA	NA	NA	NA	.03	.3	<.001	±22 aCi/m³	11 aCi/m³
	BS 2	1	NA	NA	NA	NA	.02	.2	<.001		
	BS 3	1	NA	NA	NA	NA	.03	.3	<.001		
	BS 4	1	NA	NA	NA	NA	.02	.2	<.001		
	BS 5	1	NA	NA	NA	NA	.01	.1	<.001		
	BS 6	1	NA	NA	NA	NA	.01	.1	<.001		
Gross alpha [a] radioactivity	BS 1	41	14.2	NA	.5	NA	5.4	NA	.3	±8 fCi/m³	10 fCi/m³
	BS 2	44	41.7	NA	.6	NA	5.6	NA	.3		
	BS 3	40	13.8	NA	2.0	NA	7.7	NA	.4		
	BS 4	46	16.6	NA	.9	NA	3.2	NA	.2		
	BS 5	42	6.2	NA	1.2	NA	3.9	NA	.2		
	BS 6	43	20.7	NA	1.9	NA	6.4	NA	.3		
Gross beta [c] radioactivity	BS 1	41	95.8	NA	5.7	NA	54.0	NA	.005	±70 fCi/m³	10 fCi/m³
	BS 2	44	232.1	NA	12.0	NA	56.6	NA	.006		
	BS 3	40	100.5	NA	18.1	NA	60.1	NA	.006		
	BS 4	46	84.8	NA	11.6	NA	47.6	NA	.005		
	BS 5	42	90.1	NA	12.8	NA	53.6	NA	.005		
	BS 6	43	383.6	NA	26.8	NA	74.4	NA	.007		

[a] AEC radiation protection standard (1) 2000 fCi/m³ (natural uranium).
[b] AEC radiation protection standard (1) 1000 fCi/m³ (natural thorium).
[c] AEC radiation protection standard (1) 1 nCi/m³ (gross beta).
[d] Composite samples consisting of 13 continuous samples which cover the period, 1/16/72–3/30/72.
NA, not applicable.

Table 2. Radioactive contaminants in water, Feed Material Production Center, January-December 1972

Contaminant	Sampling point [a]	Number of samples	Radionuclide concentration							95-percent confidence limit (pCi/liter)	Detection level (pCi/liter)	Standard (pCi/liter)
			Maximum		Minimum		Average		Percent of standard			
			(pCi/liter)	(μg/liter)	(pCi/liter)	(μg/liter)	(pCi/liter)	(μg/liter)				
Uranium [b]	W1	53	67	200	<1	1	4	12	0.02	±0.5	0.10	[d] 20 000
	W2	366	.50	1	.08	1	.17	<1	<.001	NA	NA	
	W3	53	17	50	<1	1	1	4	.005	±0.5	.10	
Thorium [b]	W2	[c] 6	4.90×10^{-4}	4.30×10^{-3}	3.24×10^{-4}	2.84×10^{-4}	4.17×10^{-4}	3.66×10^{-3}	<.001	NA	NA	[d] 1 000
Radium-226	W1	12	1.816	NA	<.454	NA	.908	NA	2.8	±.45	.45	[d] 30
	W2	24	.074	NA	.002	NA	.022	NA	<.001	NA	NA	
	W3	12	.908	NA	<.454	NA	.454	NA	1.4	±.45	.45	
Radium-228	W1	12	.908	NA	.454	NA	.454	NA	1.4	±.45	.45	[d] 30
	W2	24	.023	NA	.001	NA	.006	NA	<.001	NA	NA	
	W3	12	1.816	NA	<.454	NA	.908	NA	2.8	±.45	.45	
Dissolved alpha	W2	72	.970	NA	.094	NA	.293	NA	9.8	NA	NA	[e] 3
Gross beta	W1	53	454	NA	4	NA	26	NA	2.6	±9	6	[e] 1 000
	W2	366	4	NA	<1	NA	1	NA	.1	NA	NA	
	W3	53	86	NA	4	NA	15	NA	1.5	±9	6	

[a] See sampling locations shown in figure 2. W1—Miami River, upstream at Ross, Ohio; W2—Calculated addition to the river based on effluent analyses and river flow; W3—Miami River downstream at New Baltimore, Ohio.
[b] In accordance with Manual Chapter 0524 a curie of natural uranium means a total of 7.49×10^{10} dis/s and a curie of natural thorium means a total of 7.4×10^{10} dis/s.
[c] Each sample is a 1 month composite of daily 24 hour samples. Analyses were made for the first 6 months of 1972.
[d] See reference (*1*).
[e] See reference (*3*).
NA, not applicable.

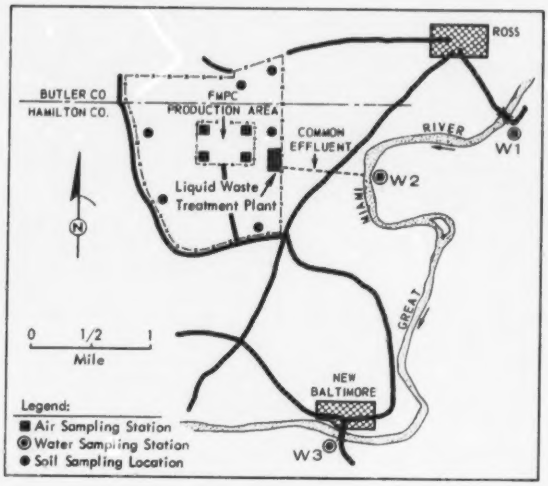

Figure 2. Air, water, and soil sampling stations, FMPC

river. Locations are shown in figure 2. At point W1, upstream from the effluent discharge, a daily grab sample is collected. At the final access point on the waste line, a Parshal Flume type water sampler collects a continuous sample which is proportional to the total flow. This sample is collected and analyzed on a daily basis. Results of these analyses, combined with river flow measurements, are used to calculate contaminant concentrations added to the river at point W2. At point W3, downstream on the river from the discharge point, 24-hour samples are collected by a continuous sampler.

Daily samples from the final access point (W2) are analyzed for uranium, alpha, and beta radioactivity. The same analyses are made on at least one sample per week from each of the river sampling points (W1 and W3). Each month, single upstream and downstream river samples collected at points W1 and W3 are analyzed for radium-226 and radium-228. Two-week composites from the waste-line final access point (W2) are analyzed for radium and 1-month composites are analyzed for thorium.

Table 2 contains information on radionuclides in water. As shown, the average concentrations of uranium, thorium, and radium added to the river was <0.001 percent of the AEC standards. The average upstream concentrations of radium-226 and radium-228 were 2.8 percent and 1.4 percent of the standard for uncontrolled areas. State criteria for gross beta and dissolved alpha radioactivity were not exceeded in the river. The calculated addition of gross dissolved alpha did average 9.8 percent of the state criteria. However, this alpha activity was due principally to uranium, for which the AEC standard is substantially higher. The more limiting state standard is intended to provide control over all alpha emitters, including radium-226, which must be kept at a concentration much lower than other less important radionuclides.

Soil monitoring

At least once each year, soil samples are collected near the 6 boundary sampling stations. Each sample consists of six cores, 2 cm in diameter and 10 cm deep. The cores are taken about 1.5 cm meters apart. These samples are analyzed for uranium to observe the possible contribution from stack effluents.

There are no standards for comparison with the results for uranium in soil listed in table 3. Although the normal value for uranium in local soil is 1–4 μg/g, there are no hazards associated with the elevated soil uranium produced by FMPC operations. External radiation from uranium is slight and the exposure contribution from these onsite concentrations would be considerably less than 1 percent of the AEC standard for people in uncontrolled areas.

Table 3. Uranium in soil, onsite locations, Feed Material Production Center, January-December 1972

Sampling point [a]	Uranium concentration			Detection level
	pCi/g (dry weight)	μg/g	95-percent confidence limit	
BS-1	0.9	2.6	±25%	0.5 μg/g
BS-2	3.9	11.8		
BS-3	14.8	44.3		
BS-4	1.5	4.4		
BS-5	2.3	6.8		
BS-6	2.5	7.4		

[a] See sampling locations shown in figure 2.

Previous coverage in *Radiation Data and Reports:*

Period	Issue
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REFERENCES

(1) U.S. ATOMIC ENERGY COMMISSION. AEC manual Standards for radiation protection, Chapter 0524. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (February 4, 1969).

(2) STATE OF OHIO DEPARTMENT OF HEALTH, WATER POLLUTION CONTROL BOARD. Regulations adopted January 28, 1972; effective February 15, 1972.

(3) STATE OF OHIO DEPARTMENT OF HEALTH, WATER POLLUTION CONTROL BOARD. Resolution establishing amended criteria of streamwater quality for various uses adopted by the board on April 14, 1970.

2. Knolls Atomic Power Laboratory[3] January–December 1972

General Electric Company
Schenectady, N.Y.

Knolls site

The Knolls site of the Knolls Atomic Power Laboratory occupies approximately 0.69 km^2 on the south bank of the Mohawk River, 8 km east of Schenectady. The facilities at this site include administrative buildings; chemistry, physics, metallurgical, engineering, and radioactive materials laboratories; critical assembly buildings; machine shops, decontamination facilities; radioactive waste storage, and processing facilities; and nuclear fuel storage and assembly buildings (figure 3).

Mohawk River and municipal waters monitoring

Samples of Mohawk River water were collected at two locations 300 and 650 meters upriver and at two locations 900 and 1400 meters downriver from the Knolls site outfall during each of three calendar quarters; ice coverage prevented collection during the first calendar quarter. One tap water sample was collected each month from the municipal water systems of Schenectady and Miskayuna, N.Y., and from these, a separate composite sample for each system was prepared and analyzed each calendar quarter. These two water systems service the area surrounding the Knolls site.

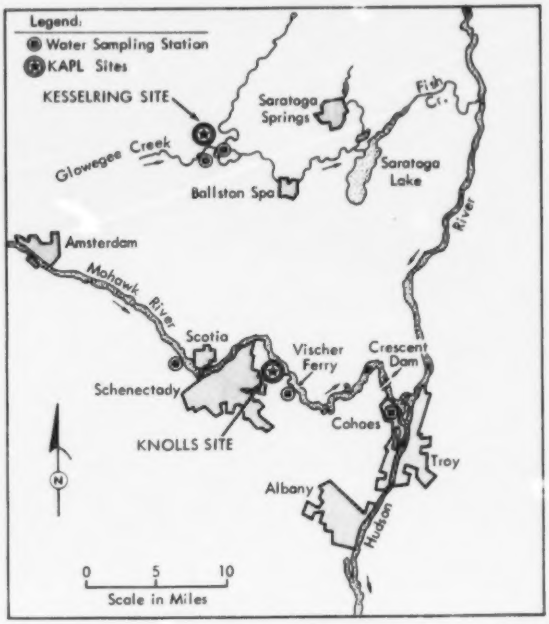

Figure 3. Environmental monitoring locations, KAPL

The Mohawk River and municipal water samples were analyzed for gross alpha and beta-gamma radioactivities using alpha proportional counters and thin mica end-window geiger counters, respectively. The detection sensitivities of the analyses were approximately 1 pCi/liter and 5 pCi/liter, respectively, which correspond to the typical concentrations found in fresh water streams, principally from natural environmental radioactivity. In the event that the gross-beta concentration of a sample exceeds levels of radioactivity concentration typically found in surface water, the sample is also analyzed for strontium-90 and cesium-137; all water samples were found to contain less than the minimum detectable activity during 1972. In addition, a monthly sample of the

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[3] Summarized from "Knolls Atomic Power Laboratory, Annual Environmental Monitoring Report, January–December 1972."

Schenectady municipal water system, which services the Knolls site, is also analyzed for tritium to determine its natural concentration in this source of water. With the exception of the analysis for tritium, each analysis involved the radiation counting of dry samples prepared by appropriate chemical procedures; i.e., chemical extraction technique for alpha analysis, water evaporation procedures for beta-gamma analysis, and chemical separation procedures for strontium-90 and cesium-137. Tritium analysis was performed using a sensitive gas counting technique with a minimum detectable activity of 200 pCi/liter.

The monitoring results for Mohawk River water and for Schenectady and Miskayuna municipal waters are summarized in table 4. The results show no statistical differences between the radioactivity concentrations in river water upstream and downstream from the Knolls site or between river water and municipal waters. Using measuring techniques which detect radioactivity concentrations occurring naturally in the river water and municipal waters, no radioactivity exceeding natural background levels was detected in Mohawk River and local municipal waters. The results show that the small amount of radioactivity released in water from the Knolls site during 1972 had no significant effect on the radioactivity levels in Mohawk River and municipal waters.

Mohawk River bottom sediment

Samples of Mohawk River bottom sediment were collected during each of three calendar quarters; ice coverage prevented collection during the first calendar quarter. The samples were collected at the upriver and downriver locations from the Knolls site with a Birge-Ekman Dredge, which samples a 15 cm by 15 cm area of the top layer of sediment to an average depth of 2.5 cm. The top layer of sediment is sampled

Table 4. Monitoring results for Mohawk River water and municipal water, 1972

Location	Number of samples	Concentration (pCi/liter)					
		Beta-gamma radioactivity			Alpha radioactivity		
		Maximum	Minimum	Average	Maximum	Minimum	Average
Mohawk River water:							
Upriver	6	[a] <5.2	[a] <4.6	[a] <5.1	[a] <0.8	[a] <0.6	[a] <0.8
Downriver	6	[a] <5.2	[a] <4.6	[a] <5.1	[a] <.8	[a] <.6	[a] <.8
Schenectady municipal water	12	[a] <5.3	[a] <4.5	[a] <4.9	[a] <.8	[a] <.6	[a] <.8
Niskayuna municipal water	12	[a] <5.3	[a] <4.5	[a] <4.9	[a] <.8	[a] <.6	[a] <.8

[a] Minimum detectable activity (MDA) values are expressed at the 95-percent confidence level. None of the water sample results exceeded the MDA values.

Table 5. Results of analysis of Mohawk River bottom sediment, 1972

Location	Number of samples	Radionuclide concentration (pCi/g wet weight)											
		Gross alpha [a]			Gross beta-gamma [b]			Cesium-137			Strontium-90		
		Maximum	Minimum	Average	Maximum	Minimum	Average	Maximum	Minimum	Average	Maximum	Minimum	Average
Upriver	6	0.45 ± 0.01	0.11 ± 0.07	0.32 ± 0.02	25 ± 8.6	15 ± 7.1	22 ± 3.1	1.7 ± 0.68	≤ 0.38	≤ 0.63 ± 0.21			
	3										0.61 ± 0.35	≤0.14	≤0.35 ± 0.17
Downriver	12	1.05 ± .02	.17 ± .07	.45 ± .01	27 ± 6.8	16 ± 6.4	22 ± 2.0	9.4 ± .92	≤ .34	2.9 ± .16			
	6										.58 ± .21	≤ .24	≤ .40 ± .11
Opposite	3	.46 ± .01	.36 ± .01	.40 ± .01	29 ± 8.1	17 ± 7.7	22 ± 3.8	.94 ± .52	≤ .36	.5 ± .27	.43 ± .33	≤ .21	< .32 ± .18

[a] The minimum detectable activity (MDA) was 0.02 pCi/g wet weight.
[b] Radioactivity was primarily natural potassium-40. The minum detectable activity (MDA) was 4.5 pCi/g wet weight.

since it should be more mobile and more accessible to marine life than deeper layers. All samples were analyzed for gross alpha activity by a chemical extraction technique, for gross beta-gamma activity by direct counting of a dried sample, and for gamma emitters by gamma spectrum analysis.

The monitoring results for Mohawk River bottom sediment for 1972 are summarized in table 5. The data indicate no statistical differences between the upriver and downriver concentrations of strontium and gross beta-gamma activity in bottom sediment and no significant increase in the average concentrations of other activities in bottom sediment downriver from the Knolls site. Although in the case of cesium-137, the maximum downriver sample concentration was several times higher than the average, this was localized and occurred near the Knolls site outfall to the river. It was attributed to operations prior to 1964. Self-imposed reductions in discharges since 1964 have curtailed further deposition of cesium-137 on the river bottom.

The average cesium-137 concentration in sediment downriver from the Knolls site corresponds to approximately 11 percent of the radioactivity concentration guide for drinking water (4). This standard is applicable to water, but for convenience and in the absence of a specific standard for sediment, is is used as a basis of comparison. This comparison, in addition to the low average levels of radioactivity in the river bottom sediment and the narrow concentration range between upriver and downriver sediment, shows that Knolls site operations are effective in protecting public health and the environment.

Air monitoring

Ventilation exhaust systems servicing radiological facilities at the Knolls site are equipped with appropriate air cleaning devices and the effluent air is continuously sampled using a filter. The resulting filter samples are collected and analyzed on a weekly basis for gross alpha and beta-gamma activities and for selected radionuclides. The detection sensitivities of the gross alpha and beta-gamma analyses were approximately 5 fCi/m^3 and 30 fCi/m^3, respectively, which correspond to the lower concentrations currently found in environmental air.

Monitoring results show that only a small quantity of airborne radioactivity was released from the Knolls site. During 1972, only 920 μCi of particulate activity and 100 μCi of iodine-131 were released. The annual average concentrations of radioactivity in the air released well within the site boundaries were less than 1 percent of the offsite radioactivity concentration guides (4).

During 1972, approximately 1.4 curies of noble gases were also released from the Knolls site. The maximum potential dose at the boundary of the Knolls site or in the offsite environment resulting from the noble gas effluents is calculated to be less than 0.1 percent of the AEC standards (4).

The monitoring results for 1972 show that the quantity of airborne radioactivity released from the Knolls site during 1972 was too small to have had any significant effect on radioactivity levels in the environment in the vicinity of Knolls site.

Perimeter monitoring

Radiation levels at the perimeter of the Knolls site were determined by thermoluminescent dosimeters located on the site security fence and at the 15 perimeter locations. The dosimeters have a minimum detection level of approximately 3 mrem and were changed and processed monthly.

Evaluation of the monitoring data shows that the radiation levels in normally occupied areas external to the site perimeter were indistinguishable from natural background.

Estimates of potential radiation dose to the public

Although the amounts of radioactivity released from the laboratory are small and the results of environmental monitoring show that laboratory operations have had no significant effect on the environment, conservative estimates of the potential radiation dose to man have been made. Some estimates considered direct exposure, such as by drinking water from the Mohawk River, and indirect pathways, such as consumption of food. It was shown that exposure to man from this radioactivity would be too low to measure and the maximum potential dose could only be estimated through conservative calculations based on the concentrations of radioactivity released. During 1972, the maximum radiation exposure to any member of the general public and the exposure to the population within an 80 km radius of the Knolls site were significantly less than 1 percent of the standards (4).

Kesselring site

The Kesselring site, located near West Milton, N.Y., is situated on a United States Government-owned reservation consisting of 15.8 km^2 located approximately 27 km north of the city of Schenectady, 14 km southwest of the city of Saratoga Springs, and 21 km northeast of the city of Amsterdam. The surrounding area is a rural, sparsely-populated region of wooded and unused farm lands through which flows the Glowegee Creek and Crook Brook, both of which flow into the Kayaderosseras Creek (figure 3). The flow eventually reaches the Hudson River, by way of Fish Creek, and thence to the Atlantic Ocean.

This site houses two operating pressurized water nuclear power plants. Additional facilities include administrative buildings, an equipment service building, a fuel service building and waste treatment operations.

The principal function of the Kesselring site is to support the U.S. Atomic Energy Commission through the operation of nuclear reactors. Regular effluent and environmental monitoring activities are conducted to assure that these operations have had no significant effect on the environment and the general public.

Water monitoring

The principal source of radioactivity considered in this report is activated corrosion and wear products from reactor plant metal surfaces in contact with reactor cooling water. Of the radionuclides which have significant half-lives (e.g., greater than 1 day), cobalt-60 is predominant in quantity, and has the most restrictive concentration guide in water established by federal regulations (4). Therefore, water releases are conservatively controlled assuming that all long-lived radioactivity is cobalt-60. Potentially radioactive water is collected and processed to reduce the concentration to the lowest practical level.

Samples of Glowegee Creek water are analyzed for radioactivity by gamma spectrometry once a month at two locations, one approximately 46 meters upstream of the point where the site enters the creek and the other approximately 460 meters downstream of the water release point (figure 3).

All Glowegee Creek water analyses results were below the minimum detectable activity concentration that may be considered valid at the 95-percent confidence level, which was 5.6 pCi/liter. The results show no statistically significant difference between the water in Glowegee Creek upstream and downstream of the site effluents.

Radioactive liquid waste is processed by filtration and deionization and monitored by analysis of samples with sensitive gamma spectrometry techniques. All water is stored in holding tanks during processing and is not released until radioactivity concentrations are below 2 percent of the AEC standards for cobalt-60 (4).

The total quantity of activity released during 1972 was less than 1.3 mCi and the total volume released to Glowegee Creek was approximately 530 Ml. Therefore, the average concentration was approximately 2.5 pCi/liter, which is less than 0.0083 percent of the AEC standard for cobalt-60 in water (4).

Sediment monitoring

Glowegee Creek bottom sediment is sampled monthly and analyzed by gamma radiation spectrometry. Sample locations are the same as those listed for Glowegee Creek water sampling. The samples are taken by scooping up the top 5 cm of sediment from the creek bottom. Each sample contains at least 500 grams of sediment.

The minimum detectable activity for cobalt-60 in sediment at the 95-percent statistical confidence level, is 0.1 pCi/g of sediment while the minimum detectable activity for the gross gamma radioactivity analysis is 0.2 pCi/g of sediment. Table 6 presents the sediment analysis results.

The results show that there is no statistically significant difference between the sediment in Glowegee Creek upstream and downstream of the site.

Table 6. Results of Glowegee Creek sediment analysis, 1972

Location	Number of samples	Radionuclide concentration (pCi/g wet weight)			
		Gross gamma			Cobalt-60 energy range [*]
		Maximum	Minimum	Average	Average
Upstream	7	13.1	8.8	11.0 ± 3.2	1.5 ± 0.4
Downstream	10	17.3	11.7	14.5 ± 3.6	1.8 ± .4

[*] The cobalt-60 energy range includes gamma energies between 1.1 and 1.4 MeV. The values shown are the result of natural potassium-40, radium and thorium in the environment; cobalt-60 was not found in any bottom sediment sample.

Plus and minus values indicate the statistical precision at the 95-percent confidence level.

Exhaust air monitoring

Ventilation air is passed through high efficiency filters before it is released through stacks. After filtration, the air is continuously monitored by moving filter-tape air particulate monitors, charcoal filters, and/or fixed filter paper samplers. Filter papers are better than 99-percent efficient for sampling submicron and larger-sized particles. The volume sampled is known and the beta-gamma activity on the filter sample is measured, either by sensitive geiger counter techniques or by beta-gamma scintillation counters. Counting results are interpreted in terms of cobalt-60 equivalent activity concentration. Air samples are not counted for a minimum of 48 hours to allow the short-lived natural radioactivity to decay off. The only detectable gaseous radionuclide is argon-41; however, it has a half-life of less than 2 hours and does not build up in the environment.

The air monitoring data indicates no activity was released above the minimum detectable concentration at the 95-percent confidence level. Using the minimum detectable concentration, the total activity released was less than 3 mCi during 1972. The average particulate concentration at the Kesselring site boundary, which is a minimum of 1.4 km from the nearest stack, has been estimated to be less than 0.0005 percent of the AEC standard for cobalt-60 in air (4).

Perimeter radiation monitoring

Perimeter environmental surveys are performed by placing thermoluminescence dosimeters around the site security fence. The maximum monthly average evaluated at the site perimeter shows that the annual exposure rate did not exceed the natural radiation level for this geographic location. These results indicate that the Kesselring site operations have had no significant effect on the radiation levels in the surrounding area.

Estimates of potential radiation dose to the public

Although the amounts of radioactivity released from the Kesselring site are small and the results of environmental monitoring show that site operations have had no significant effect on the environment, conservative estimates of the potential radiation dose to man have been made. Some estimates considered direct exposure, such as by drinking the water in Glowegee Creek, and indirect pathways, such as consumption of fish from Glowegee Creek. It was shown that exposure to man from this radioactivity would be too low to measure and the maximum potential dose could only be estimated through calculations based on the concentrations of radioactivity released. During 1972, the maximum radiation exposure to any member of the general public and the exposure to the population within an 80-km radius of the Kesselring site were significantly less than 1 percent of the standards (4).

Windsor site

The Windsor site, near Windsor, Conn., is situated on a United States Government-owned 4. hm^2 plot of land located approximately 8 km north of Hartford, Conn. The surrounding area is a rural and industrial region, through which

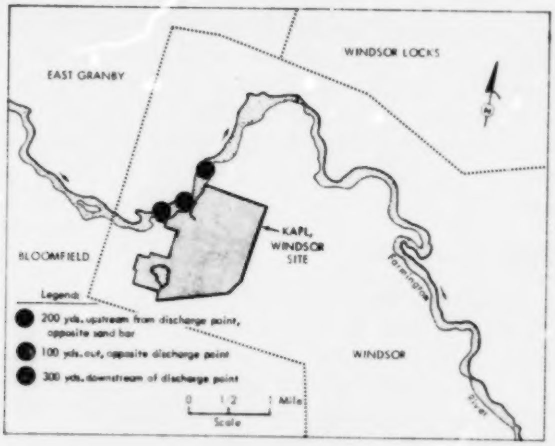
EAST GRANBY
WINDSOR LOCKS
BLOOMFIELD
KAPL, WINDSOR SITE
WINDSOR
Farmington River
Legend:
● 200 yds. upstream from discharge point, opposite sand bar
● 100 yds. out, opposite discharge point
● 300 yds. downstream of discharge point
0 1/2 1 Mile
Scale

Figure 4. Environmental monitoring locations, KAPL-Windsor site (S1C Prototype)

flows the Farmington River, which empties into the Connecticut River and thence to Long Island Sound (figure 4).

This site has one pressurized water nuclear power plant. Additional facilities include an equipment service building, waste treatment operations, classrooms, and administrative offices. The primary function of the Windsor site is the training of personnel in the operation of this type of power plant. Regular effluent and environmental monitoring activities are conducted to assure that these operations have had no signfiicant effect on the environment and the general public.

Water monitoring

The principal source of radioactivity in this report is activated corrosion and wear products from reactor plant metal surfaces in contact with reactor cooling water. Of the radionuclides present which have significant half-lives (e.g., greater than 1 day), cobalt-60 is predominant in quantity and has the most restrictive concentration guide in water, established by federal regulations. Therefore, water releases are conservatively controlled assuming that all long-lived radioactivity is cobalt-60. Potentially radioactive water is controlled and processed to reduce the concentration to the lowest practical level.

Samples of Farmington River water are collected quarterly for radioactivity analysis by gamma radiation spectrometry. Figure 5 shows the three sampling locations, one approximately 180 meters upstream, another approximately 90 meters out from shore opposite the water release point, and the third approximately 270 meters downstream from it. The samples are analyzed for gross gamma activity and specifically for cobalt-60.

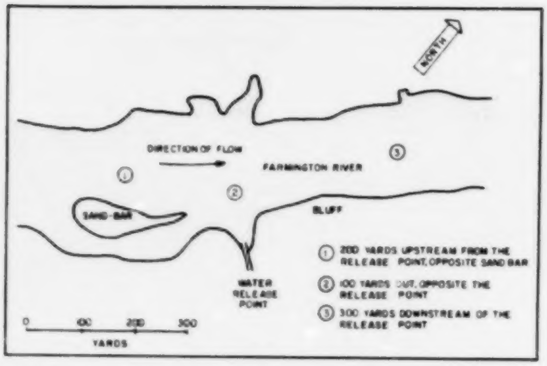
NORTH
DIRECTION OF FLOW
FARMINGTON RIVER
①
②
③
SAND-BAR
BLUFF
WATER RELEASE POINT
① 200 YARDS UPSTREAM FROM THE RELEASE POINT, OPPOSITE SAND BAR
② 100 YARDS OUT, OPPOSITE THE RELEASE POINT
③ 300 YARDS DOWNSTREAM OF THE RELEASE POINT
0 100 200 300
YARDS

Figure 5. Farmington River sampling locations

Prior to release to the Farmington River, water from the Windsor site is collected, processed and sampled. The total activity released in the liquid waste during 1972 was less than 1 mCi. The concentration of radioactivity in water leaving the site was less than 1 percent of the AEC standard for cobalt-60 in effluent water (4).

No cobalt-60 activity was detected in the river water. The gross gamma and cobalt-60 concentrations were less than 50 pCi/liter, which was the minimum detectable concentration at the 95-percent confidence level. The results show no statistically significant difference between the radioactivity concentration in Farmington River water upstream, opposite, and downstream of the effluent point.

It is concluded that the small quantity of activity in water released from the Windsor site in 1972 has had no significant effect on the environment.

Sediment monitoring

Farmington River bottom sediment is sampled quarterly and analyzed by gamma radiation spectrometry. Sample locations are the same as those shown in figure 5 for river water sampling. The samples are taken to a depth of 2.5 cm with a "clam shell" dredge. Specific gravity at standard dry weight for these samples is approximately 1.5 g/cm^3.

Table 7 lists the results of Farmington River bottom sediment sample analyses for 1972. The gross gamma energy range includes all pertinent radionuclides and covers a wide gamma energy range, while the cobalt-60 energy range includes gammas from a relatively narrow range around the cobalt-60 energies. The minimum detectable activity for both the cobalt-60 and gross gamma energy analyses, at the 95-percent confidence level, was 0.1 pCi/g of sediment. No cobalt-60 was detected in any sediment sample, however, natural potassium-40 was observed in most samples.

The results show no statistically significant differences between the upstream, opposite, and downstream concentrations, indicating that the Windsor site has been successful in protecting the river environment.

Table 7. Results of Farmington River sediment analysis, 1972

Location	Number of samples	Radionuclide concentration (pCi/g)			
		Gross gamma			Cobalt-60 [a]
		Maximum	Minimum	Average	Average
Upstream	[b]3	3.1	1.4	2.3±0.1	0.5±0.1
Opposite	[b]3	2.4	2.2	2.3± .1	.4± .1
Downstream	[b]3	2.6	2.1	2.3± .1	.5± .1

[a] The cobalt-60 energy range includes gamma energies between 1.1 and 1.4 MeV. The values shown are the result of natural potassium-40, radium and thorium in the environment; cobalt-60 was not found in any bottom sediment sample.

[b] Samples not obtained during first quarter because the river was frozen.

Plus and minus values indicate the statistical precision at the 95-percent confidence level.

Exhaust air monitoring

Ventilation air is directed through high efficiency filters before it is released through stacks. The main stack is monitored by a fixed filter sampling system which is changed weekly and analyzed by sensitive radiation counting equipment calibrated to a cobalt-60 standard. The chemistry laboratory is monitored continuously by a moving filter air particulate detector with adjustable alarm and chart recorder. The only detectable gaseous radionuclide is argon-41; however, it has a half-life of less than 2 hours and does not build up in the environment.

The total particulate activity released from the Windsor site during 1972 was less than 1 mCi. The average particulate concentration at the Windsor site boundary has been estimated to be less than 0.0002 percent of the AEC standard for cobalt-60 in air (*4*).

Perimeter radiation monitoring

The site perimeter fence is monitored with film badges at eight locations. This film is changed and evaluated monthly. The annual average exposure rate did not exceed the natural radiation level for this geographic location. It is concluded that Windsor site operations have had no significant effect on the natural background radition levels of the surrounding area.

Estimates of potential radiation dose to the public

Although the amounts of radioactivity released from the Windsor site are small and the results of environmental monitoring show that site operations have had no significant effect on the environment, conservative estimates of the potential radiation dose to man have been made. Some estimates considered direct exposure, such as by drinking the water in the Farmington River and indirect pathways, such as consumption of food. It was shown that exposure to man from this radioactivity would be too low to measure and the maximum potential dose could only be estimated through conservative calculations based on the concentrations of radioactivity released. During 1972, the maximum radiation exposure to any member of the general public and the exposure to the population within an 80 km radius of the Windsor site were significantly less than 1 percent of the standards (*4*).

Previous coverage in *Radiation Data and Reports:*

Period	Issue
January–December 1971	June 1973

REFERENCE

(*4*) U.S. ATOMIC ENERGY COMMISSION. U.S. Atomic Energy Commission Manual Chapter 0524 (October 8, 1968).

Nuclear Power Reactors in the United States
June 30, 1974

Each quarter year, the Atomic Energy Commission releases information on the status of all present and proposed civilian nuclear power generating units in the United States. This information is reproduced for interested readers of *Radiation Data and Reports.*

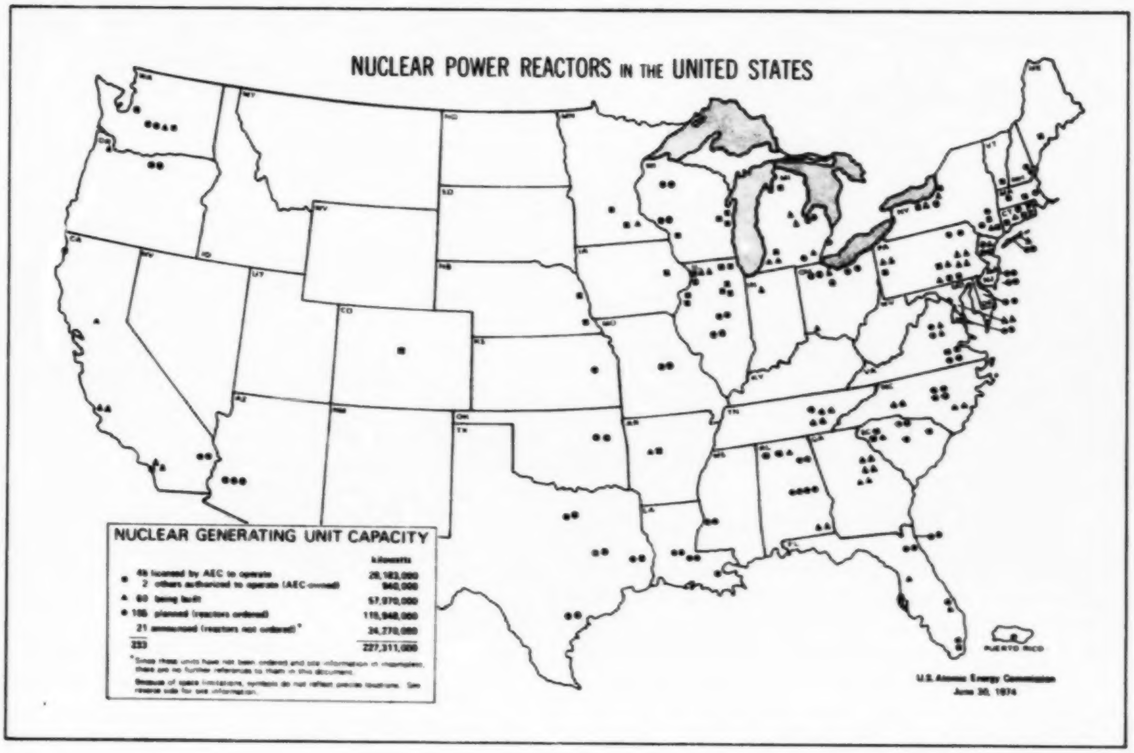
NUCLEAR POWER REACTORS IN THE UNITED STATES
NUCLEAR GENERATING UNIT CAPACITY
kilowatts
licensed by AEC to operate
2 others authorized to operate (AEC-owned)
940,000
60 being built
57,970,000
105 planned (reactors ordered)
110,948,000
21 announced (reactors not ordered)*
34,270,000
233
227,311,000
PUERTO RICO
U.S. Atomic Energy Commission
June 30, 1974

Figure 1. Nuclear power reactors in the United States, June 30, 1974

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SITE	PLANT NAME	CAPACITY (Net Kilowatts)	UTILITY	COMMERCIAL OPERATION
ALABAMA				
Decatur	Browns Ferry Nuclear Power Plant: Unit 1	1,065,000	Tennessee Valley Authority	1974
Decatur	Browns Ferry Nuclear Power Plant: Unit 2	1,065,000	Tennessee Valley Authority	1974
Decatur	Browns Ferry Nuclear Power Plant: Unit 3	1,065,000	Tennessee Valley Authority	1975
Dothan	Joseph M. Farley Nuclear Plant: Unit 1	829,000	Alabama Power Co.	1975
Dothan	Joseph M. Farley Nuclear Plant: Unit 2	829,000	Alabama Power Co.	1977
Chilton County	Central Alabama Nuclear Plant: Unit 1	1,[illegible]00,000	Alabama Power Co.	1982
Chilton County	Central Alabama Nuclear Plant: Unit 2	[illegible],200,000	Alabama Power Co.	1983
Elmore County	Central Alabama Nuclear Plant: Unit 3	1,200,000	Alabama Power Co.	1984
Elmore Kounty	Central Alabama Nuclear Plant: Unit 4	1,200,000	Alabama Power Co.	1985
Scottsboro	Bellefonte Nuclear Plant: Unit 1	1,213,000	Tennessee Valley Authority	1979
Scottsboro	Bellefonte Nuclear Plant: Unit 2	1,213,000	Tennessee Valley Authority	1980
ARIZONA				
Wintersburg	Palo Verde Nuclear Generation Station: Unit 1	1,270,000	Arizona Public Service	1981
Wintersburg	Palo Verde Nuclear Generating Station: Unit 2	1,270,000	Arizona Public Service	1982
Wintersburg	Palo Verde Nuclear Generating Station: Unit 3	1,270,000	Arizona Public Service	1984
ARKANSAS				
Russellville	Arkansas Nuclear One: Unit 1	850,000	Arkansas Power & Light Co	1974
Russellville	Arkansas Nuclear One: Unit 2	912,000	Arkansas Power & Light Co	1976
CALIFORNIA				
Humboldt Bay	Humboldt Bay Power Plant: Unit 3	65,000	Pacific Gas and Electric Co.	1963
San Clemente	San Onofre Nuclear Generating Station: Unit 1	430,000	So. Calif. Ed. & San Diego Gas & El. Co	1968
San Clemente	San Onofre Nuclear Generating Station: Unit 2	1,140,000	So. Calif. Ed. & San Diego Gas & El. Co	1979
San Clemente	San Onofre Nuclear Generating Station: Unit 3	1,140,000	So. Calif. Ed. & San Diego Gas & El. Co	1980
Diablo Canyon	Diablo Canyon Nuclear Power Plant: Unit 1	1,084,000	Pacific Gas and Electric Co.	1975
Diablo Canyon	Diablo Canyon Nuclear Power Plant: Unit 2	1,106,000	Pacific Gas and Electric Co.	1976
Clay Station	Rancho Seco Nuclear Generating Station	804,000	Sacramento Municipal Utility District	1974
*	–	1,128,000	Pacific Gas & Electric Co.	1981
*	–	1,128,000	Pacific Gas & Electric Co.	1982
Vidal	Vidal Generating Station: Unit 1	770,000	Southern California Edison Co.	1981
Vidal	Vidal Generation Station: Unit 2	770,000	Southern California Edison Co.	1982
COLORADO				
Platteville	Ft. St. Vrain Nuclear Generating Station	330,000	Public Service Co. of Colorado	1974
CONNECTICUT				
Haddam Neck	Haddam Neck Plant	575,000	Conn. Yankee Atomic Power Co.	1968
Waterford	Millstone Nuclear Power Station: Unit 1	652,100	Northeast Utilities	1971
Waterford	Millstone Nuclear Power Station: Unit 2	828,000	Northeast Utilities	1974
Waterford	Millstone Nuclear Power Station: Unit 3	1,156,000	Northeast Utilities	1979
DELAWARE				
Summit	Summit Power Station: Unit 1	770,000	Delmarva Power & Light Co.	1980
Summit	Summit Power Station: Unit 2	770,000	Delmarva Power & Light Co.	1982
FLORIDA				
Florida City	Turkey Point Station: Unit 3	693,000	Florida Power & Light Co.	1972
Florida City	Turkey Point Station: Unit 4	693,000	Florida Power & Light Co.	1973
Red Level	Crystal River Plant: Unit 3	825,000	Florida Power Corp.	1974
Ft. Pierce	St. Lucie Plant: Unit 1	801,000	Florida Power & Light Co.	1975
Ft. Pierce	St. Lucie Plant: Unit 2	801,000	Florida Power & Light Co.	1979
*	–	1,300,000	Florida Power Corp.	1983
*	–	1,300,000	Florida Power Corp.	1986
Jacksonville	Offshore Unit 1	1,150,000	Jacksonville Electric Authority	1982
Jacksonville	Offshore Unit 2	1,150,000	Jacksonville Electric Authority	1984
GEORGIA				
Baxley	Edwin I. Hatch Nuclear Plant: Unit 1	786,000	Georgia Power Co.	1974
Baxley	Edwin I. Hatch Nuclear Plant: Unit 2	795,000	Georgia Power Co.	1978
Waynesboro	Alvin W. Vogtle, Jr. Plant: Unit 1	1,113,000	Georgia Power Co.	1980
Waynesboro	Alvin W. Vogtle, Jr. Plant: Unit 2	1,113,000	Georgia Power Co.	1981
Waynesboro	Alvin W. Vogtle, Jr. Plant: Unit 3	1,113,000	Georgia Power Co.	1982
Waynesboro	Alvin W. Vogtle, Jr. Plant: Unit 4	1,113,000	Georgia Power Co.	1983
ILLINOIS				
Morris	Dresden Nuclear Power Station: Unit 1	200,000	Commonwealth Edison Co.	1960
Morris	Dresden Nuclear Power Station: Unit 2	809,000	Commonwealth Edison Co.	1970
Morris	Dresden Nuclear Power Station: Unit 3	809,000	Commonwealth Edison Co.	1971
Zion	Zion Nuclear Plant: Unit 1	1,050,000	Commonwealth Edison Co.	1973
Zion	Zion Nuclear Plant: Unit 2	1,050,000	Commonwealth Edison Co.	1974
Cordova	Quad-Cities Station: Unit 1	800,000	Comm. Ed. Co. Ia.-Ill. Gas & Elec. Co.	1972
Cordova	Quad-Cities Station: Unit 2	800,000	Comm. Ed. Co. Ia.-Ill. Gas & Elec. Co.	1972
Seneca	LaSalle County Nuclear Station: Unit 1	1,078,000	Comm. Ed. Co. Ia.	1978
Seneca	LaSalle County Nuclear Station: Unit 2	1,078,000	Comm. Ed. Co. Ia.	1979
Bryon	Byron Station: Unit 1	1,120,000	Comm. Edison Co.	1980
Bryon	Byron Station: Unit 2	1,120,000	Comm. Edison Co.	1981
Braidwood	Braidwood: Unit 1	1,120,000	Comm. Edison Co.	1980
Braidwood	Braidwood: Unit 2	1,120,000	Comm. Edison Co.	1981
Clinton	Clinton Nuclear Power Plant: Unit 1	955,000	Illinois Power Co.	1980
Clinton	Clinton Nuclear Power Plant: Unit 2	955,000	Illinois Power Co.	1982
INDIANA				
Porter County	Bailly Generating Station	660,000	Northern Indiana Public Service Co.	1979
IOWA				
Palo	Duane Arnold Energy Center: Unit 1	569,000	Iowa Electric Light and Power Co.	1974
KANSAS				
Burlington	Wolf Creek Generation Station: Unit 1	1,150,000	Kansas Gas & Electric - Kansas City P & L	1981
LOUISIANA				
Taft	Waterford Generating Station	1,113,000	Louisiana Power & Light Co.	1977
St. Francisville	River Bend Station: Unit 1	934,000	Gulf States Utilities Co.	1980
St. Francisville	River Bend Station: Unit 2	934,000	Gulf States Utilities Co.	1981
Alliance	St. Rosalie Generating Station: Unit 1	1,200,000	Louisiana Power & Light Co.	1982
Alliance	St. Rosalie Generating Station: Unit 2	1,200,000	Louisiana Power & Light Co.	1984

Figure 1. Nuclear power reactors in the United States, June 30, 1974—continued

SITE	PLANT NAME	CAPACITY (Net Kilowatts)	UTILITY	COMMERCIAL OPERATION
MAINE				
Wiscasset	Maine Yankee Atomic Power Plant	790,000	Maine Yankee Atomic Power Co.	1972
MARYLAND				
Lusby	Calvert Cliffs Nuclear Power Plant: Unit 1	845,000	Baltimore Gas and Electric Co.	1974
Lusby	Calvert Cliffs Nuclear Power Plant: Unit 2	845,000	Baltimore Gas and Electric Co.	1975
Nanjemoy	Douglas Point Project: Unit 1	1,178,000	Potomac Electric Power Co.	1980
Nanjemoy	Douglas Point Project: Unit 2	1,178,000	Potomac Electric Power Co.	1981
MASSACHUSETTS				
Rowe	Yankee Nuclear Power Station	175,000	Yankee Atomic Electric Co.	1961
Plymouth	Pilgrim Station: Unit 1	664,000	Boston Edison Co.	1972
Plymouth	Pilgrim Station: Unit 2	1,180,000	Boston Edison Co.	1980
MICHIGAN				
Big Rock Point	Big Rock Point Nuclear Plant	75,000	Consumers Power Co.	1965
South Haven	Palisades Nuclear Power Station	700,000	Consumers Power Co.	1971
Lagoona Beach	Enrico Fermi Atomic Power Plant: Unit 2	1,093,000	Detroit Edison Co.	1976
Lagoona Beach	Enrico Fermi Atomic Power Plant: Unit 3	1,171,000	Detroit Edison Co.	1981
Bridgman	Donald C. Cook Plant: Unit 1	1,060,000	Indiana & Michigan Electric Co.	1974
Bridgman	Donald C. Cook Plant: Unit 2	1,060,000	Indiana & Michigan Electric Co.	1976
Midland	Midland Nuclear Power Plant: Unit 1	492,000	Consumers Power Co.	1980
Midland	Midland Nuclear Power Plant: Unit 2	818,000	Consumers Power Co.	1979
St. Clair County	Greenwood: Unit 2	1,200,000	Detroit Edison Co.	1980
St. Clair County	Greenwood: Unit 3	1,200,000	Detroit Edison Co.	1981
MINNESOTA				
Monticello	Monticello Nuclear Generating Plant	545,000	Northern States Power Co.	1971
Red Wing	Prairie Island Nuclear Generating Plant: Unit 1	530,000	Northern States Power Co.	1973
Red Wing	Prairie Island Nuclear Generating Plant: Unit 2	530,000	Northern States Power Co.	1974
MISSOURI				
Fulton	Callaway Plant: Unit 1	1,150,000	Union Electric Co.	1981
Fulton	Callaway Plant: Unit 2	1,150,000	Union Electric Co.	1983
MISSISSIPPI				
Port Gibson	Grand Gulf Nuclear Station: Unit 1	1,250,000	Mississippi Power & Light Co.	1979
Port Gibson	Grand Gulf Nuclear Station: Unit 2	1,250,000	Mississippi Power & Light Co.	1981
NEBRASKA				
Fort Calhoun	Ft. Calhoun Station: Unit 1	457,400	Omaha Public Power District	1973
Brownville	Cooper Nuclear Station	778,000	Nebraska Public Power District and Iowa Power and Light Co.	1974
NEW HAMPSHIRE				
Seabrook	Seabrook Nuclear Station: Unit 1	1,200,000	Public Service of N.H.	1979
Seabrook	Seabrook Nuclear Station: Unit 2	1,200,000	Public Service of N.H.	1981
NEW JERSEY				
Toms River	Oyster Creek Nuclear Power Plant: Unit 1	640,000	Jersey Central Power & Light Co.	1969
Forked River	Forked River Generating Station: Unit 1	1,070,000	Jersey Central Power & Light Co.	1979
Salem	Salem Nuclear Generating Station: Unit 1	1,090,000	Public Service Electric and Gas, N.J.	1975
Salem	Salem Nuclear Generating Station: Unit 2	1,115,000	Public Service Electric and Gas, N.J.	1976
Salem	Hope Creek Generating Station: Unit 1	1,067,000	Public Service Electric and Gas, N.J.	1981
Salem	Hope Creek Generating Station: Unit 2	1,067,000	Public Service Electric and Gas, N.J.	1982
Little Egg Inlet	Atlantic Generating Station: Unit 1	1,150,000	Public Service Electric and Gas, N.J.	1980
Little Egg Inlet	Atlantic Generating Station: Unit 2	1,150,000	Public Service Electric and Gas, N.J.	1981
*	–	1,150,000	Public Service Electric and Gas, N.J.	1983
*	–	1,150,000	Public Service Electric and Gas, N.J.	1984
NEW YORK				
Indian Point	Indian Point Station: Unit 1	265,000	Consolidated Edison Co.	1962
Indian Point	Indian Point Station: Unit 2	873,000	Consolidated Edison Co.	1973
Indian Point	Indian Point Station: Unit 3	965,000	Consolidated Edison Co.	1974
Scriba	Nine Mile Point Nuclear Station: Unit 1	625,000	Niagara Mohawk Power Co.	1969
Scriba	Nine Mile Point Nuclear Station: Unit 2	1,080,000	Niagara Mohawk Power Co.	1978
Ontario	R. E. Ginna Nuclear Power Plant: Unit 1	490,000	Rochester Gas & Electric Co.	1970
Brookhaven	Shoreham Nuclear Power Station	819,000	Long Island Lighting Co.	1977
Scriba	James A. Fitzpatrick Nuclear Power Plant	821,000	Power Authority of State of N.Y.	1973
Jamesport	Jamesport 1 –	1,150,000	Long Island Lighting Co.	1981
Jamesport	Jamesport 2 –	1,150,000	Long Island Lighting Co.	1983
Oswego	Sterling Nuclear: Unit 1	1,150,000	Rochester Gas & Electric Co.	1982
NORTH CAROLINA				
Southport	Brunswick Steam Electric Plant: Unit 1	821,000	Carolina Power and Light Co.	1975
Southport	Brunswick Steam Electric Plant: Unit 2	821,000	Carolina Power and Light Co.	1974
Cowans Ford Dam	Wm. B. McGuire Nuclear Station: Unit 1	1,180,000	Duke Power Co.	1976
Cowans Ford Dam	Wm. B. McGuire Nuclear Station: Unit 2	1,180,000	Duke Power Co.	1977
Bonsal	Shearon Harris Plant: Unit 1	915,000	Carolina Power & Light Co.	1981
Bonsal	Shearon Harris Plant: Unit 2	915,000	Carolina Power & Light Co.	1982
Bonsal	Shearon Harris Plant: Unit 3	915,000	Carolina Power & Light Co.	1983
Bonsal	Shearon Harris Plant: Unit 4	915,000	Carolina Power & Light Co.	1984
Davie County	Perkins Nuclear Station: Unit 1	1,280,000	Duke Power Co.	1981
Davie County	Perkins Nuclear Station: Unit 2	1,280,000	Duke Power Co.	1982
Davie County	Perkins Nuclear Station: Unit 3	1,280,000	Duke Power Co.	1982
OHIO				
Oak Harbor	Davis Besse Nuclear Power Station: Unit 1	906,000	Toledo Edison-Cleveland El. Illum. Co.	1976
Oak Harbor	Davis Besse Nuclear Power Station: Unit 2	906,000	Toledo Edison-Cleveland El. Illum. Co.	1981
Oak Harbor	Davis-Besse Nuclear Power Station: Unit 3	906,000	Toledo Edison-Cleveland El. Illum. Co.	1983
Perry	Perry Nuclear Power Plant: Unit 1	1,205,000	Cleveland Electric Illuminating Co.	1979
Perry	Perry Nuclear Power Plant: Unit 2	1,205,000	Cleveland Electric Illuminating Co.	1980
Moscow	Wm. H. Zimmer Nuclear Power Station: Unit 1	810,000	Cincinnati Gas & Electric Co.	1977
Moscow	Wm. H. Zimmer Nuclear Power Station: Unit 2	1,170,000	Cincinnati Gas & Electric Co.	1982

Figure 1. Nuclear power reactors in the United States, June 30, 1974—continued

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SITE	PLANT NAME	CAPACITY (Net Kilowatts)	UTILITY	COMMERCIAL OPERATION
OKLAHOMA				
Inola	Black Fox Nuclear Station: Unit 1	950,000	Public Service of Oklahoma	1982
Inola	Black Fox Nuclear Station: Unit 2	950,000	Public Service of Oklahoma	1984
OREGON				
Prescott	Trojan Nuclear Plant: Unit 1	1,130,000	Portland General Electric Co.	1975
*	—	1,260,000	Portland General Electric Co.	1981
*	—	1,260,000	Portland General Electric Co.	1983
PENNSYLVANIA				
Peach Bottom	Peach Bottom Atomic Power Station: Unit 1	40,000	Philadelphia Electric Co.	1967
Peach Bottom	Peach Bottom Atomic Power Station: Unit 2	1,065,000	Philadelphia Electric Co.	1974
Peach Bottom	Peach Bottom Atomic Power Station: Unit 3	1,055,000	Philadelphia Electric Co.	1974
Pottstown	Limerick Generating Station: Unit 1	1,065,000	Philadelphia Electric Co.	1979
Pottstown	Limerick Generating Station: Unit 2	1,065,000	Philadelphia Electric Co.	1980
Shippingport	Shippingport Atomic Power Station: Unit 1	90,000	Duquesne Light Co.	1957
Shippingport	Beaver Valley Power Station: Unit 1	852,000	Duquesne Light Co.-Ohio Edison Co.	1975
Shippingport	Beaver Valley Power Station: Unit 2	852,000	Duquesne Light Co.-Ohio Edison Co.	1979
Goldsboro	Three Mile Island Nuclear Station: Unit 1	819,000	Metropolitan Edison Co.	1974
Goldsboro	Three Mile Island Nuclear Station: Unit 2	905,000	Jersey Central Power & Light Co.	1976
Berwick	Susquehanna Steam Electric Station: Unit 1	1,050,000	Pennsylvania Power and Light	1979
Berwick	Susquehanna Steam Electric Station: Unit 2	1,050,000	Pennsylvania Power and Light	1981
Fuller	Fulton Generating Station: Unit 1	1,140,000	Philadelphia Electric Co.	1981
Fuller	Fulton Generating Station: Unit 2	1,140,000	Philadelphia Electric Co.	1983
SOUTH CAROLINA				
Hartsville	H. B. Robinson S.E. Plant: Unit 2	700,000	Carolina Power & Light Co.	1971
Seneca	Oconee Nuclear Station: Unit 1	886,000	Duke Power Co.	1973
Seneca	Oconee Nuclear Station: Unit 2	886,000	Duke Power Co.	1973
Seneca	Oconee Nuclear Station: Unit 3	886,000	Duke Power Co.	1974
Broad River	Virgil C. Summer Nuclear Station: Unit 1	900,000	South Carolina Electric & Gas Co.	1978
Lake Wylie	Catawba Nuclear Station: Unit 1	1,153,000	Duke Power Co.	1979
Lake Wylie	Catawba Nuclear Station: Unit 2	1,153,000	Duke Power Co.	1980
Cherokee County	Cherokee Nuclear Station: Unit 1	1,280,000	Duke Power Co.	1982
Cherokee County	Cherokee Nuclear Station: Unit 2	1,280,000	Duke Power Co.	1983
Cherokee County	Cherokee Nuclear Station: Unit 3	1,280,000	Duke Power Co.	1984
TENNESSEE				
Daisy	Sequoyah Nuclear Power Plant: Unit 1	1,140,000	Tennessee Valley Authority	1975
Daisy	Sequoyah Nuclear Power Plant: Unit 2	1,140,000	Tennessee Valley Authority	1976
Spring City	Watts Bar Nuclear Plant: Unit 1	1,169,000	Tennessee Valley Authority	1978
Spring City	Watts Bar Nuclear Plant: Unit 2	1,169,000	Tennessee Valley Authority	1978
Oak Ridge	Clinch River Breeder Reactor Plant	350,000	U.S. Government	1980
TEXAS				
Glen Rose	Commanche Peak Steam Electric Station: Unit 1	1,150,000	Texas Utilities Services Inc.	1980
Glen Rose	Commanche Peak Steam Electric Station: Unit 2	1,150,000	Texas Utilities Services Inc.	1982
Jasper	Blue Hills: Unit 1	918,000	Gulf States Utilities	1982
Jasper	Blue Hills: Unit 2	918,000	Gulf States Utilities	1982
Wallis	Allens Creek: Unit 1	1,150,000	Houston Lighting & Power Co.	1980
Wallis	Allens Creek: Unit 2	1,150,000	Houston Lighting & Power Co.	1982
Matagorda County	South Texas Project	1,250,000	Central Power & Light Co.	1980
Matagorda County	South Texas Project	1,250,000	Central Power & Light Co.	1982
VERMONT				
Vernon	Vermont Yankee Generating Station	513,900	Vermont Yankee Nuclear Power Corp.	1972
VIRGINIA				
Gravel Neck	Surry Power Station: Unit 1	788,000	Virginia Electric & Power Co.	1972
Gravel Neck	Surry Power Station: Unit 2	788,000	Virginia Electric & Power Co.	1973
Mineral	North Anna Power Station: Unit 1	898,000	Virginia Electric & Power Co.	1975
Mineral	North Anna Power Station: Unit 2	898,000	Virginia Electric & Power Co.	1976
Mineral	North Anna Power Station: Unit 3	907,000	Virginia Electric & Power Co.	1977
Mineral	North Anna Power Station: Unit 4	907,000	Virginia Electric & Power Co.	1978
Gravel Neck	Surry Power Station: Unit 3	859,000	Virginia Electric & Power Company	1980
Gravel Neck	Surry Power Station: Unit 4	859,000	Virginia Electric & Power Company	1981
WASHINGTON				
Richland	N Reactor WPPSS Steam	850,000	Atomic Energy Commission	1966
Richland	WPPSS No. 1	1,206,000	Washington Public Power Supply System	1980
Richland	WPPSS No. 2	1,103,000	Washington Public Power Supply System	1977
Satsop	WPPSS No. 3	1,242,000	Washington Public Power Supply System	1981
Sedro Woolley	Skagit Nuclear Project	1,200,000	Puget Sound Power & Light	1982
WISCONSIN				
Genoa	Genoa Nuclear Generating Station	50,000	Dairyland Power Cooperative	1971
Two Creeks	Point Beach Nuclear Plant: Unit 1	497,000	Wisconsin Michigan Power Co.	1970
Two Creeks	Point Beach Nuclear Plant: Unit 2	497,000	Wisconsin Michigan Power Co.	1972
Carlton	Kewaunee Nuclear Power Plant: Unit 1	541,000	Wisconsin Michigan Power Co.	1973
Ft. Atkinson	Koshkonong Nuclear Plant: Unit 1	900,000	Wisconsin Electric Power Co.	1981
Ft. Atkinson	Koshkonong Nuclear Plant: Unit 2	900,000	Wisconsin Electric Power Co.	1982
Durand	Tyrone Energy Park: Unit 1	1,150,000	Northern States Power Co.	1982
Durand	Tyrone Energy Park: Unit 2	1,150,000	Northern States Power Co.	1983
PUERTO RICO				
Puerto De Jobos	Aguirre Nuclear Power Plant	583,000	Puerto Rico Water Resources Authority	1979
*	—	1,205,000	Tennessee Valley Authority	1980
*	—	1,205,000	Tennessee Valley Authority	1981
*	—	1,205,000	Tennessee Valley Authority	1980
*	—	1,205,000	Tennessee Valley Authority	1981
*	—	1,200,000	New England Electric System	1982
*	—	1,200,000	New England Electric System	1982

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* Site not selected.

Figure 1. Nuclear power reactors in the United States, June 30, 1974—continued

Reported Nuclear Detonations, August 1974

(Includes seismic signals presumably from foreign nuclear detonations)

A nuclear test with a yield of less than 20 kilotons was conducted August 14, 1974, by the Atomic Energy Commission at its Nevada Test Site.

Seismic signals, presumably from a Soviet underground nuclear explosion, were recorded by the United States. The signals originated at 11:00 a.m., e.d.t., August 14, 1974, from the Tazovskiy Peninsula area in Northwestern Siberia and were equivalent to those of an underground nuclear explosion in the yield range of 20 to 200 kilotons.

Seismic signals from a large Soviet underground nuclear test were recorded by the United States. The signals originated at approximately 6 a.m., e.d.t., August 29, 1974, in the Novaya Zemlya Island area in the Arctic Ocean and indicated a yield of 1 to 3 megatons.

A nuclear test in the low-intermediate yield range (20 to 200 kilotons TNT equivalent) was conducted by the Atomic Energy Commission at its Nevada Test Site on August 30, 1974.

Not all of the nuclear detonations in the United States are announced immediately, therefore, the information in this section may not be complete. A complete list of announced U.S. nuclear detonations may be obtained upon request from the Division of Public Information, U.S. Atomic Energy Commission, Washington, D.C. 20545.

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SYNOPSES

Synopses of reports, incorporating a list of key words, are furnished below in reference card format for the convenience of readers who may wish to clip them for their files.

HF SPECTRAL ACTIVITY IN THE WASHINGTON, D.C. AREA. *Richard A .Tell, John C. Nelson, and Norbert N. Hankin. Radiation Data and Reports, Vol. 15,* September 1974, pp. 549–558.

The results of preliminary study on the spectral activity of the high frequency band from 0 to 100 MHz with emphasis on the 2–22 MHz band segment are presented. In the 0–2 MHz band segment, which includes the AM standard broadcast region, the highest mean number of signals recorded in any one hour was approximately 14.3 that occurred at 1800 e.d.t., the minimum mean number of signals observed was 8.2 occurring at 0200 e.d.t., and the maximum integral relative power density occurred at 1800 e.d.t.

In the 2–22 MHz band, the peak band activity and peak integral spectral power density both occur between 1800 and 2400 e.d.t. The maximum integral power density is about 20 dB greater during this time period than at other times.

For the overall band of 0–100 MHz, the highest activity appears to occur from about 0900 to 1800 e.d.t. There is a lull in activity that occurs in the early morning hours (0200 to 0600 e.d.t.). The inactivity of nonbroadcast sources is generally correlated with the overall band activity. Measurements show that signals of nonbroadcast origin are significantly lower in amplitude than signals in the broadcast bands.

KEYWORDS: Microwave, radiofrequency, Washington, D.C.

AN EVALUATION PROCEDURE FOR A NUCLEAR MEDICAL DEPARTMENT. *David Metz, Stanley J. Malsky, Charles J. Blatt, David B. Hayt, Arthur Frie, Peter A. Betar, John Macca, and Donald Simon. Radiation Data and Reports. Vol. 15,* September 1974, pp. 559–566.

This study presents administrative, health physics, educational, instrumentation and space requirements for departments of nuclear medicine. The data were recorded from answers to a questionnaire and personal interviews with personnel in hospitals with varying bed capacities. Finally, a visual inspection was made of each department by personnel conducting the interview.

KEYWORDS: Hospital, medical procedure, New York, radioisotopes.

SIGNIFICANCE OF STABLE IODINE-127 IN MILK. *William J. Kelleher* and *Harvey R. Prins. Radiation Data and Reports, Vol. 15,* September 1974, pp. 567–573.

The unexpected high concentrations of stable iodine in milk found when studying the specific activity concept for iodine-129 around a nuclear fuels reprocessing plant led to an evaluation of the use of iodine-129 to iodine ratio in milk samples to calculate population doses. In order to use specific activity to calculate thyroid dose, it will be necessary to establish values for the concentration of iodine in thyroids. If a constant concentration of iodine in the thyroid is assumed and there is a high enough concentration of iodine in the milk to be able to assume that milk is the only source of iodine in the thyroid, a relationship between thyroid dose and the iodine-129 to iodine or iodine-131 to iodine ratios can be developed. The use of specific activity in milk to determine dose will have the greatest application in evaluating the man-rem dose from the discharge of iodine-129 from fuel reprocessing plants.

KEYWORDS: Doses, iodine-127, iodine-131, milk, population, specific activity, thyroid.